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PEDAGOGY AS AN ACTUALIZATION OF COMPLEMENTARITY IN BHUTAN

By

Jerome K. Turner

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

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Dr. Linda Thompson

Daisy Sawada

External Examiner

Date: June 21, 1989

DEDICATION

To the children of Bhutan.

Abstract

The principle of complementarity, as used in quantum mechanics and as revealed through research on hemispheric specialization of the human brain, suggests that there are two complementary modes of knowing. It was the goal of this investigation to defend such an assertion, and to portray how complementarity could be considered as a theoretical structure for the concept of ethnomathematics.

The principle of complementarity states that two descriptions or sets of concepts, though mutually exclusive, are nonetheless both necessary for a complete description of the phenomenon. The Nobel Laureate, Niels Bohr, firmly believed that the concept of complementarity had wide application outside the realm of physics and declared that one day complementarity would be taught in schools and become part of public education.

The Brazilian mathematics educator, Ubiratan D'Ambrosio has been credited with coining the term ethnomathematics, and in this research it related to how counting, ordering, sorting, measuring and weighing were inherent within the songs, games, and movement of Bhutanese children.

Employing a descriptive methodology, a case study involving two lower primary classes, their teachers, the teacher trainees and the investigator, as a participant observer, was conducted during the school year of 1987 at the Teachers' Training Centre and Demonstration School (TTC/DS), Paro, Bhutan. The research focused upon a pedagogical process involving the complementary relationship between mathematics within the world of play and within the world of school, of Bhutanese children.

The analysis of data presented the analytical term: propositional theme. In the context of this investigation, it was defined as a recurring behavioral pattern which denoted a fundamental truth that was shown through demonstration to be an actualization of complementarity. Three such propositional themes were derived from the data.

It was concluded that the teaching of elementary school mathematics through the songs, games, and movement of Bhutanese children could be considered to be an actualization of complementarity; and that complementarity could be regarded as a theoretical foundation for ethnomathematics.

Lastly, implications of this research were drawn for the education of the whole child, for future research focusing upon complementarity and ethnomathematics, for Bhutan's New Approach to Primary Education (NAPE), and, finally, for the survival of children in the Third World.

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CHAPTER ONE

INTRODUCTION

This introductory chapter is divided into three parts. The initial section delineates the two major purposes of the investigation and concludes by revealing the research questions. Secondly, the significance of this investigation for the country of Bhutan is described and, lastly, the overall organization of the dissertation is presented.

The Purpose

Bhutan is a small, landlocked nation hidden among the high Himalayas. In the early 1960s this remote Kingdom opened its doors to the world and adopted a policy of modernization. Naturally, education became a focal point for development within this country, which is classified by the United Nations as one of the thirty-one least developed countries of the world.

What is of such vital consequence to the progress of education in Bhutan, is a uniqueness in the pedagogy of elementary school mathematics. Barcellos (1981), reporting on the subject of "Universal Primary Education", remarks how primary school curriculum throughout the world is basically the same but the needs of children in developing countries are certainly very different from children in industrialized nations. Barcellos continues by emphasizing the extreme importance of how mathematics is taught to children in the Third World. He asserts:

> Certainly the way that it's taught to them makes it very difficult for them really to apply it, because they've learnt it from outside of their culture. Hence, they can't see how the mathematics and science that they learned in school relates at all to the world in which they live. (p. 122)

He concludes by stating that "the revision of curricula to reflect the needs of the indigenous culture is the project of the present day" (p. 122).

This research proposes to describe and examine a medium of instruction for elementary school mathematics which has a meaningful relationship to the cultural world in which Bhutanese children live; that is, the world of their play and movement activities. Furthermore, it is a purpose of this investigation to portray that this pedagogical approach is an actualization of the concept of complementarity.

It was in Como, Italy, during the 1927 International Congress of Physics that the Nobel Laureate, Niels Bohr for the first time introduced publicly his formulation of the principle of complementarity (Holton, 1973). Bohr's proposal was fundamentally that we must accept the inescapable dichotomy that the nature of light is both particle-like and wave-like depending upon how it is observed. Bohr states that these two descriptions of this phenomenon are complementary; that is, each perspective is required to give a complete description of atomic reality. By definition, the principle of complementarity states that two descriptions or sets of concepts, though mutually exclusive, are nonetheless both necessary for a complete description of the situation (Murdock, 1987).

Niels Bohr firmly believed that the concept of complementarity had wide application outside the realm of physics and stated that one day complementarity would be taught in schools and become part of public education (Holton, 1973). Further, Niels Bohr's deep commitment to the principle of complementarity, and to the antiquity of its roots, is revealed by the fact that he chose the Buddhist t'ai chi symbol for his

coat-of-arms when he was knighted by the Government of Denmark. Capra (1983) reveals the significance of this decision in communicating the complementary relationship between Eastern and Western thought by stating that:

> In choosing this symbol for his coat-of-arms together with the inscription *Contraria sunt complementa* (Opposites are complementary), Niels Bohr acknowledged the profound harmony between ancient Eastern wisdom and modern Western science. (p. 175)

Consequently, the Far East, Buddhist nation of Bhutan, was an ideal setting for an investigation focusing upon the furthering of complementarity as a new epistemology.

The second purpose of this investigation centers upon how complementarity can become a theoretical structure for the concept of ethnomathematics. The Brazilian mathematics educator, Ubiratan D'Ambrosio, in 1980, first presented the concept of ethnomathematics publicly at the 4th International Congress on Mathematics Education. He created this concept in the context of developing countries who are struggling for a more meaningful way to help children learn mathematics.

Scott (1985) went on to define ethnomathematics as the following:

> Ethnomathematics lies at the confluence of mathematics and cultural anthropology. At one level, it is what might be called "math in the environment" or "math in the community". At another, related level, ethnomathematics is the particular (and perhaps peculiar) way of classifying, ordering, counting and measuring [and weighing]. (p. 2)

Consequently, as D'Ambrosio intends, the country of Bhutan, being classified by the United Nations as one of the thirty-one least developed countries of the world, was an ideal setting to investigate how complementarity can be considered as a theoretical framework for the concept of ethnomathematics. Further, in a letter to the researcher dated February 25, 1986 Ubiratan D'Ambrosio stated:

> I was quite pleased to receive your papers. Parts I and II of your thesis proposal bring an important new dimension to activity oriented Math Education.

> We have been trying for some years to put together Math and Art Education (including dance) and the progress depends upon a theoretical framework. I feel you are in the right direction.

Research Questions. In summary, the two research questions to be examined in this investigation are, first, how pedagogy, which involves teaching elementary school mathematics through the songs, games and movement of Bhutanese children, can be an actualization of complementarity; and, second, how complementarity can be a theoretical structure for ethnomathematics.

The Significance of the Research for Bhutan

The two teacher training institutions in the country of Bhutan, namely, the National Institute of Education (NIE), Samchi, and the Teachers' Training Centre and Demonstration School (TTC/DS), Paro, jointly planned and implemented the same primary teacher education curriculum in July of 1986. This core curriculum is outlined in the document *Primary Teacher Certificate Course: NIE, Samchi and TTC, Paro, July, 1985*. This curriculum recommends teaching primary school mathematics through such activities as: sandplay, stoneplay, circle games, throw and target games, marble games, rhythm and movement, as well as, the games of archery, khuru, and dego. Thus, a value of this research is the documentation of data to examine and hopefully support this pedagogical recommendation.

Secondly, a new primary school curriculum and pedagogical approach was implemented by the Department of Education in 12 pilot schools along with the Demonstration School of TTC/DS in March of 1986. This curriculum development project came under the title of the New Approach to Primary Education (NAPE). The

NAPE approach places the child at the centre of learning and the child's immediate environment becomes the focus and stimulus for subject matter studied. The former Director of Education, Dasho Jigme Thinley, stated at the first NAPE conference in August of 1986, that the challenge for teachers within the NAPE program is to effectively integrate learning by rote with learning through active participation--truly a complementary task (Turner, 1988b). Therefore, research is needed to describe and examine this process before nation wide implementation in the early 1990s.

Lastly, 14,000 children will die today in the Third World because of dehydration due to diarrhea. The major causes for this health problem are malnutrition and the lack of clean drinking water. As David Werner (1977) so aptly states: "Malnutrition causes diarrhea, diarrhea causes malnutrition" (p. 154). In Bhutan, dehydration due to diarrhea is the major killer of children below the age of five years. Obviously, an improvement in basic literacy and numeracy skills would help to alleviate this tragic situation.

In Bhutan only 1:4 of school age children attend primary schools and only 1:4 will actually complete class six. With this awareness, the Royal Government of Bhutan believes that the NAPE curriculum development project will help children acquire necessary skills for life prior to returning to their village farm. More specifically, Bhutanese educators hope that the children who do not complete primary school will gain mathematical and language literacy skills such that they could comprehend the instructions on a "UNICEF Rehydration Salts" package, for example, and be able to prepare the mixture through proper measurement. By assisting children to gain mathematical literacy through an integrated pedagogical approach and through activities

meaningful to Bhutanese children, Bhutan's educators believe that schooling will be more effective. This research hopes to support that belief.

It seems most appropriate at this time to state the following by His Majesty, Jigme Singye Wangchuck, King of Bhutan, which was delivered as a message for the International Year of the Child in 1979:

> The year 1979, proclaimed by the General Assembly [of the United Nations] to be the International Year of the Child, brings into sharp focus the pressing needs of millions of children all over the world. In our pre-occupation with other problems that confront us, we tend to overlook or to relegate to a position of secondary importance, the task of provision of these needs. Yet, it is perhaps the most urgent challenge that faces the International community today. Children are our treasures, they hold the promise of the future and therefore it is only right that they should be given every opportunity to develop their physical, mental and spiritual potentials to the fullest extent in an environment free of fear. It is, therefore, of primary concern that every individual and Government makes concerted effort to remove all the barriers that prevent the child from growing into a secure and healthy being. (p. i)

Organization of the Thesis

This dissertation consists of seven chapters. Chapter Two comprehensively states the theoretical implications of this investigation. It presents the principle of complementarity as developed in the field of quantum mechanics and portrays how the concept of complementarity has been extended by the most recent research on hemispheric specialization of the human brain. Chapter Two concludes by indicating that the principle of complementarity, as used in quantum mechanics and as revealed through research on hemispheric specialization of the human brain, symbolizes two complementary modes of knowing: the intuitive and the rational.

Chapter Three introduces the reader to the Eastern Himalayan Kingdom of Bhutan and depicts the importance of education in the development of this Third World nation. Next, the concept of ethnomathematics is defined and its importance for the pedagogy of mathematics in Bhutan is indicated. Chapter Four shows how the theoretical orientation of this research permeates the entire investigation including the methodology. The rationale for a case study, with the researcher as participant observer, is given and the case study is presented as the best means to investigate and build upon the theoretical propositions of the research. Further the actual methodological procedures of the investigation are delineated.

Chapter Five presents the qualitative data collected, at the Teachers' Training Centre and Demonstration School (TTC/DS) during the 1987 school year, in a comprehensive, nonevaluative and descriptive form. This chapter intends to create an opportunity for the reader to intuitively connect the data to the theoretical orientation of the research, and to create a visual picture such that one is able to envision oneself in Bhutan.

The subsequent chapter will evaluate and interpret the data in light of the theoretical propositions of the investigation. The analytical term of "propositional theme" is presented as a means by which to examine the data. Lastly, Chapter Seven summarizes the research, and states how the principle of complementarity has been extended as a form of epistemology and thus as an original contribution to knowledge.

CHAPTER TWO

COMPLEMENTARITY

The principle of complementarity is the theoretical foundation of this thesis. The concept of complementarity, as used in quantum mechanics and as revealed through research on the hemispheric specialization of the human brain, suggests there are two complementary modes of knowing. It is the goal of this chapter to defend such an assertion.

The Principle of Complementarity

Quantum mechanics has been labelled the "new physics" (Heisenberg, 1963). It has its origin with Max Planck's theory of "quanta", and with the concept of "relativity", which originated from Albert Einstein's special theory of relativity in 1905 (Planck, 1936). Planck discovered that the energy of heat radiation is not emitted continuously but appears in the form of "energy packets" which Einstein called quanta (Capra, 1983). Hence, quantum mechanics may be explained by the conception of a "quantum", as a quantity of something, a specific amount, and the term "mechanics" as the study of motion (Bohr, 1958b). Zukav (1979) concludes his explanation of this branch of physics by stating that:

> Quantum mechanics is the study of the motion of quantities. Quantum theory says that nature comes in bits and pieces (quanta), and quantum mechanics is the study of this phenomenon. (p. 19)

Thus, we have the science of the infinitely small, which has been termed "atomic physics" (Bohr, 1958b). Capra (1983) makes known that at the beginning of the 20th century it was ascertained through the study of X-rays that atoms have some form of structure. This research resulted in the discovery of extremely small particles called electrons, protons and neutrons. However, no one has ever seen an atom or the elementary particles it is said to be composed of, and because of this, the concept of probability has become one of the fundamental principles of the new physics (Heisenberg, 1963)

Heisenberg's Uncertainty Principle

The significance of the concept of probability in the study of subatomic particles is disclosed through Heisenberg's "uncertainty principle." Werner Heisenberg, one of the founders of quantum mechanics, revealed that the exact position and precise velocity of an electron can never be simultaneously known. He did this by an ingenious, imaginary experiment in which a single electron would be shot into a dark chamber completely void of all other atoms. A scientist equipped with a microscope would see what went on in the chamber if he directed a light beam into it. Then the question that Heisenberg put forth was: What would happen when a light photon (a quantum of radiant energy) hits the electron? Obviously the electron would be knocked astray. By the very act of lighting up the electron's movement, the electron's pathway is disrupted. Thus, Heisenberg concluded that it is impossible to know the electron's exact position and its precise momentum at the same time (Bohr, 1958b; Capra, 1983; Planck, 1936). Consequently, Heisenberg turned to the theory of chance and proved that the probability of an electron's position at a given time could be known. It is interesting to note that Einstein's deepest apprehension about the theory of quantum

mechanics, is often expressed in these terms: "God does not play dice" (Capra, 1983, p. 343). However, Einstein did conclude that Heisenberg's interpretation of quantum theory, represents a consistent system of thought (Capra, 1983).

The profoundness of Heisenberg's uncertainty principle is the realization that the experimenter must *choose* by the selection of his experiment whether he is going to measure the exact position *or* precise momentum of a particle. This profoundness is revealed by the well known physicist from Princeton University, John Wheeler and his colleagues:

> May the universe in some strange sense be "brought into being" by participation of those who participate?. . . The vital act is the incontrovertible new concept given by quantum mechanics. It strikes down the term "observer" of classical theory, the man who stands safely behind the thick glass wall and watches what goes on without taking part. It can't be done, quantum mechanics says. (Wheeler, Thorne & Misner, 1973, p. 1273)

Heisenberg's uncertainty principle, which was formulated in 1927, gave the first indication of complementary relations between physical concepts (Holton, 1973). Position and momentum are complementary in a restricted sense, in that they cannot both at the same time be discovered with high precision; that is, the more exactness that is obtained in one measurement, the less it is possible to ascertain in the other.

Historically, this leads to the question of the nature of light, and whether light is particle-like or wave-like. Holton (1973) reports that physicists were unhappy with being coerced in different situational contexts to use two contradictory theories of light, they being the classical wave theory and the quantum theory. In 1924 Einstein expressed this frustration:

> We now have two theories of light, both indispensable, but, it must be admitted, without any logical connection between them, despite twenty years of colossal effort by theoretical physicists. (cited in Holton, 1973, p. 117)

In an effort to resolve this paradox Weiner Heisenberg and Niels Bohr worked diligently together in late 1926 and early 1927 at the Bohr Institute in Denmark. This period has been described by Heisenberg as a time filled with intense activity, restless emotions and the desire to reach a goal. Heisenberg states that "the physical interpretation of quantum mechanics was the central theme of all conversations between Bohr and myself" (1971, p. 16). Heisenberg further reveals that he and Bohr became anxious and irritable, and Bohr decided to go away on a skiing vacation to Norway which was in February of 1927. It was during this holiday period that Bohr formulated the principle of complementarity (Rothenberg, 1983).

It was in Como, Italy, during the 1927 International Congress of Physics that Niels Bohr for the first time introduced publicly his conception and formulation of the principle of complementarity (Holton, 1973). Bohr's proposal was fundamentally that we must accept the inescapable dichotomy that the nature of light is both particle-like and wave-like depending upon how it is observed. Bohr states that these two descriptions of this phenomenon are complementary; that is, each perspective is required to give a complete description of atomic reality and both are applied within the limitations governed by Heisenberg's uncertainty principle (Murdock, 1987).

Blackburn (1971) further explains the notion of complementarity:

> Electrons behave in ways that can be accounted for by thinking of them as particles; but they are not particles, since they also (under different conditions of observation) behave in ways that can be accounted for by thinking of them as waves. Only the complementary description is complete and, to the best of our knowledge, correct. (p. 1004)

By definition, the principle of complementarity states that two descriptions or sets of concepts, though mutually exclusive, are nonetheless both necessary for a complete description of the situation (Murdock, 1987). Therefore, in order to fully explain the

phenomenon of light and electron behavior, the dual properties of wave and particle are both necessary, despite their mutual exclusiveness. In conclusion, historians practically equate the "Copenhagen Interpretation of Quantum Mechanics" with Bohr's principle of complementarity (Holton, 1973).

Complementarity as the Basis for a New Epistemology

Focusing on the subject of "Complementarity Beyond Physics", Holton (1973) states that:

> We can now ask: What was Bohr's real ambition for the complementarity conception? It certainly went far beyond dealing with the paradoxes in the physics of the 1920's. Not only were some of the roots of the complementarity principle outside physics, but so also was its intended range of application. (p. 149)

With reference to the roots of complementarity, it is doubtful whether Niels Bohr read William James' *The Principles of Psychology* (1891) prior to his formulation of the notion of complementarity (Holton, 1973). However, there is little doubt that after 1927, reading it must have strengthened Bohr's belief that complementarity was a concept that could be applied to other domains of knowledge, rather than just the purely physical systems that led him to its formulation (Stephenson, 1986a).

Bohr himself stated that William James had had a significant influence upon him. In an interview on November 17, 1962 with the well known historian of science, Thomas S. Kuhn, and Aage Peterson, Bohr's long-time assistant, Bohr stated the following in response to the question of the relevance of philosophy in his early thoughts:

> William James is really wonderful in the way he makes it clear--I think. I read the book, or a paragraph called. . . No, what is that called? It is called "The Stream of Thoughts", where he in a most clear manner shows that it is quite impossible to analyze things in terms of--I don't know what to call it, not atoms, I mean simply if you have some things. . . they are so connected that if

> you try to separate them from each other, it just has nothing to do with the actual situation. I think we shall really go into these things, and I know something about William James. (cited in Holton, 1973, p. 137)

Historically speaking, the concept of complementarity was initially introduced to Western psychological literature by William James (1891) in his *The Principles of Psychology* (Stephenson, 1986a). James states:

> It must be admitted, therefore, that in certain persons at least, the total possible consciousness may be split into parts which co-exist but mutually ignore each other, and share the objects of knowledge between them. More remarkable still, they are complementary. (p. 206)

As well, Bohr firmly believed in the importance of psychology as a science and how complementarity could assist in understanding and explaining psychological phenomena. Bohr (1950) affirms:

> Recognition of complementary relationship is not least required in psychology, where the conditions for analysis and synthesis of experience exhibit striking analogy with the situation in atomic physics. In fact, the use of words like *thoughts* and *sentiments*, equally indispensable to illustrate the diversity of psychical experience, pertain to mutually exclusive situations characterized by a different drawing of the line of separation between subject and object. (p. 54)

Bohr (1958a) strongly proposed that a unity of knowledge could be achieved on the basis of the complementarity principle and thus wrote over two dozen papers on this subject (Holton, 1973). Bohr points out:

> As I shall attempt to show, the study of atoms, which was to entail such far-reaching consequences and whose progress has been on world-wide cooperation, not only has deepened our insight into a new domain of experience, but has thrown new light on general problems of knowledge. (p. 164)

Bohr (1958a) wrote extensively about the application of the notion of complementarity to biology, psychology, physics and social anthropology. He firmly believed that his conclusions had wide application outside of physics and that one day complementarity would be taught in schools and become part of public education (Holton, 1973). For

Niels Bohr, the principle of complementarity was a foundation for all human knowledge (Rothenberg, 1983).

Most recently, theoretical and empirical studies have been mounting in support of Bohr's beliefs. Rothenberg (1983) while writing about the scientific creativity of Niels Bohr, relates Bohr's creation of complementarity to a "janusian" formulation of simultaneous antitheses. Janus was a Roman god whose different faces were oriented in opposite directions and hence was able to view opposing phenomenon simultaneously. Rothenberg continues by stating that Bohr was a scientific theorist given to synthesis and holistic perspectives, who arrived at the principle of complementarity through a conceptualization of the entire context of the phenomenon being investigated.

Lefebvre (1984) reveals that Bohr's idea of complementarity was understood as successful metaphor; in addition, Lefebvre has also found evidence to depict how the principle of complementarity may be utilized as the basis for a model of ethical cognition. Lefebvre (1984) proclaims:

> The analysis of the Boolean model of ethical cognition has demonstrated that a law similar to the principle of complementarity is realized in the model: "interference of feelings" is incompatible with the correct registration of inner intentions. . . . Therefore, the principle of complementarity can be considered as a fundamental law of the universe with the subject included in it. We can suppose that the law generates both the quantum-mechanical peculiarities of the physical world and the mechanism's of man's ethical cognition. (pp. 243-244)

Further support for Niels Bohr's beliefs have been ascertained by using the principle of complementarity to describe psychological phenomena. Feigenberg (1986) explores the principle of complementarity in psychological phenomena by depicting hypnotic experiments that yield contradictory results. The author argues that difficulties in describing ambiguous phenomena that clash with common sense are encountered not

just in the study of hypnosis but also in the investigation of the unconscious. He concludes his article by asserting that the principle of complementarity occupies a necessary place in explaining paradoxical psychological events. In addition, Wolf (1985) demonstrates the profound connection between human consciousness and quantum physics, while Modell (1985), in an article entitled *The Two Contexts of the Self*, discloses:

> I do believe that the principle of complementarity points a way out of the dilemma of the ego and the self. That is, the principle of complementarity allows us to accept what is unreconcilable without attempting the strain of a synthesis, reduction or mutual dissolution. (p. 82)

In 1986 William Stephenson published two articles in *The Psychological Record* dealing with William James, Niels Bohr and complementarity. He concluded these articles by declaring: "Thus, complementarity is indeed fundamental, as Bohr considered, for solving the problem of analysis and synthesis of psychological experiences involving communicability, notably language and all that this involves" (1986b, p. 540).

Finally, the entire November, 1985 issue of the *Journal of Counseling and Development* is devoted to a paradigm shift in philosophic outlook in contemporary Western culture. More specifically, the authors focus on the relevance of quantum theory to counseling and personality theory and a need for a new vision of reality. Newton and Caple (1985) state that "The purpose of this special issue is to discuss a changing view of the world and look at this shift as it affects the theory and practice of counseling and therapy" (p. 163). These authors along with Lucas (1985) and Bozarth (1985) use quantum theory and the new physics as a theoretical foundation for this

paradigm shift. Specifically, they refer to the writings of Max Planck, Werner Heisenberg and Niels Bohr and of course Bohr's principle of complementarity.

Some Critical Commentary

It is now time to present an opposing view to the use of Bohr's principle of complementarity, and more generally the new physics as a wholely new epistemology, applicable to human behavior.

Philip Baumel, Professor of Physics, City College of the City University of New York, in 1986 published an article entitled: *On the Questionable Applications of Concepts from Physics to Human Behavior: A Response to the November 1985, Journal of Counseling and Development Issue*. He proclaims, "Frankly, I am dismayed that so distorted a view of physics and of the work of Kuhn appears in a scholarly journal" (p. 663). He continues by asserting:

> The fact is, modern physics is describable and understandable only in mathematical terms. Verbal descriptions, even by the best physicists, are at best metaphors and at worst misleading distortions. Then to take these metaphors and extend them well outside their domain of meaning, such as the field of human behavior, is ludicrous. (p. 663)

Further, Baumel (1986) declares that the use of physics in a journal dealing with counseling is irrelevant and that the arts and sciences of human behavior should not look to a discipline such as physics to answer their dilemmas. Baumel concludes his article by affirming that:

> Physicists know a good deal about nature, but I do not think that physics has very much to say that is useful about the behavior of people. It seems to me that the human sciences have suffered too much for too long from physics envy. (p. 664)

Holton (1973) has also indicated that many other physicists regard Bohr's belief, that the complementarity principle could be extended far beyond atomic physics,

to be radical and mysterious. However, two prominent physicists, notably, J. Robert Oppenheimer (1954), and M. A. Tuve (1967), have emphatically agreed with Bohr.

On May 9, 1966, Merle A. Tuve, a physicist at the Carnegie Institute in Washington, D.C. was presented with the "Third Cosmos Club Award." Tuve entitled his acceptance speech, *Physics and the Humanities--The Verification of Complementarity*. He posed such questions as: What are the fundamental contributions of modern physics to the areas of the good life, to the full and meaningful experience of living? What specific elements of importance does physics reveal for individual persons, for you and me and for whole societies, among them our own Western civilization? Has physics made contributions which may be relevant to people who have inherited the culture of the Far East, and view life from an Oriental philosophy?

Tuve (1967) answered these queries by stating that:

> I shall draw your attention to one basic clearcut result of modern theoretical physics which has, in my judgement immeasurably wide and deep significance for every man. The verified necessity for us to accept two very different views of natural events, mutually irreducible one to the other, a necessity which has been given the name *complementarity*, is one great gift of physics in our epoch to the thinking of all humanity. (pp. 44-45)

Contrary to Baumel (1986), Tuve concludes his remarks by pointing out that in his opinion, physics is a part of and participates with vigor in the fine arts and the humanities.

J. Robert Oppenheimer (1954) has also written on the notion of complementarity, and how it is an age-old inner awareness which is the most commonplace philosophical experience of every human being. On speaking of the analogies between atomic physics and human affairs, Oppenheimer states:

> It is my thesis that generally the new things we have learned in science, and specifically what we have learned in atomic physics do provide us with valid and relevant and greatly needed analogies to human problems lying outside the present domain of science or its present borderlands. (p. 8)

Later in his book entitled, *Science and the Common Understanding*, Oppenheimer (1954) portrayed that he was strongly in agreement with Bohr, by making reference to the complementary nature of conscious life and its physical interpretation. Oppenheimer conveyed that this relationship would be an enduring element in human understanding and an exemplification of a psychophysical parallelism. More concretely, he spoke of the complementary relation between the cognitive and the affective sides of our nature; that is, the relation between knowledge and emotion. Oppenheimer eloquently states:

> To be touched with awe, or humour, to be moved by beauty, to make a commitment or a determination, to understand some truth--these are complementary modes of the human spirit. All of them are part of man's spiritual life. None can replace the others, and where one is called for the others are in abeyance. (p. 90)

Bohr (1958a), professing that states of our mind require a typical complementary mode of description, concurs with Oppenheimer by stating:

> Indeed, the use of words like "thought" and "feeling" does not refer to a firmly connected causal chain, but to experiences which exclude each other because of different distinctions between the conscious content and the background which we loosely term ourselves. (p. 174)

East and West

Oppenheimer (1954) also reveals that the general notions of human understanding which are portrayed by discoveries in atomic physics are not unheard of or entirely new. "Even in our own culture they have a history, and in Buddhist and Hindu thought a more considerable and central place" (p. 8). Therefore, what theoretical physicists like Niels Bohr and J. Robert Oppenheimer have done through the

formulation of atomic theory is to present an exemplification and a refinement of ancient wisdom (Capra, 1982, 1983).

Bohr (1958b) realized that eastern philosophy, which represents the religious beliefs of Hinduism, Buddhism and Taoism, had recognized and described the principles of quantum mechanics in their own unique way. He points out:

> For a parallel to the lesson of atomic theory regarding the limited applicability of such customary idealisations, we must in fact turn to quite other branches of science, such as psychology, or even to that kind of epistemological problems with which already thinkers like Buddha and Lao Tse have been confronted, when trying to harmonize our position as spectators and actors in the great drama of existence. (pp. 19-20)

This once again reveals, that over the years Bohr came to regard the principle of complementarity as more and more significant, and extended it far beyond the original context from which it was derived. Bohr (1958a) discloses:

> The fact that human cultures developed under different conditions of living, exhibit such contrasts with respect to established traditions and social patterns allows one, in a certain sense, to call such cultures complementary. (p. 174)

Further, Bohr (1963), while writing on the parallel between other domains of knowledge and atomic theory, asserts that this is not a vague connection or analogy but a distinct logical relationship. Bohr emphatically states:

> It is significant that . . . in other fields of knowledge, we are confronted with situations reminding us of the situation in quantum physics. Thus, the integrity of living organisms, and the characteristics of conscious individuals and human cultures present features of wholeness, the account of which implies a typical complementarity mode of description. . . . We are not dealing with more or less vague analogies, but with clear examples of logical relations which, in different contexts, are met with in wider fields. (p. 7)

Bohr (1958a) used atomic theory and specifically the principle of complementarity to explain the historical reality that the human mind is capable of two kinds of knowledge, which have been labelled the intuitive and the rational, and

traditionally have been linked with religion and science, respectively. Oppenheimer (1954) strengthens this premise by stating:

> These two ways of thinking, the way of time and history and the way of eternity and of timelessness, are both part of man's effort to comprehend the world in which he lives. Neither is comprehended in the other nor reducible to it. They are as we have learned to say in physics, complementary views, each supplementing the other, neither telling the whole story. (p. 75)

By drawing our attention to the parallel between quantum theory and eastern philosophy, Bohr and Oppenheimer have illustrated the complementary relationship between the East and West as cultures, and between science and religion as domains of knowledge.

Ornstein (1972) points out that in the Western part of the world, the intuitive, religious kind of knowledge takes second place to the rational, scientific knowledge, while in contrast, the opposite is the case in the East. Buddhists speak of a higher and lesser knowledge and link the lower knowledge with various sciences, and the higher with spiritual awareness. Such an Eastern view is held in Bhutan.

Capra (1983) discloses that Chinese philosophy has stressed the complementary nature of the intuitive and the rational, and consequently developed two complementary philosophical traditions, Taoism and Confucianism, to deal with the two kinds of wisdom. Moreover, the Chinese have visually represented these two modes of consciousness by the *t'ai chi* symbol of the archetypal pair *yin* and *yang* (see Figure 1).

Bhutan is the only country in the world where Mahayana Buddhism is the state religion and all Bhutanese art reflects Buddhist religious beliefs (Kelley, 1987). Religious art is primarily found in the *dzongs* (religious fortresses) of Bhutan's 18

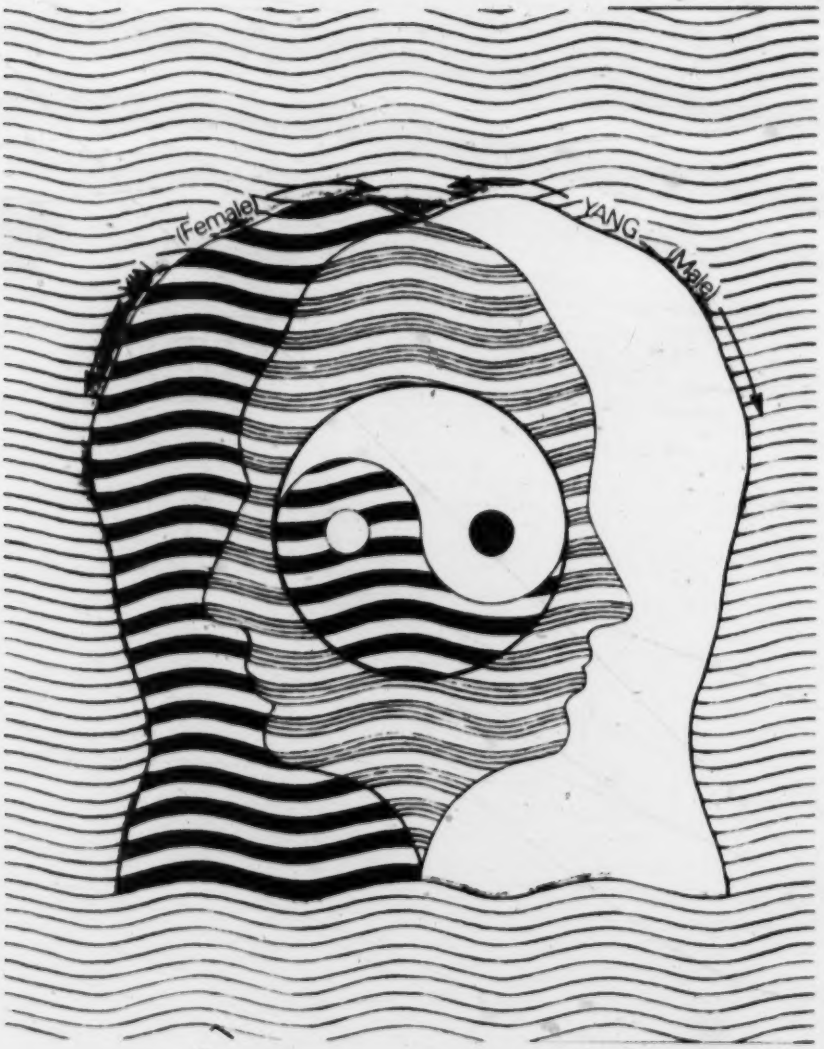

Figure 1. The t'ai chi symbol representing the complementary relationship between the polar opposites: "yin and yang." From *Maps of the Mind* (p.21) by C. Hampden-Turner, 1981, London: Mitchell Beazley. Copyright 1981 by Mitchell Beazley. Reprinted by permission.

governmental districts and the t'ai chi symbol of yin and yang is often located at the centre of these paintings (Hasrat, 1980).

Edward Kelley (1987), an art historian, and former director of the Cultural Resource Centre, Social Cultural Division, Department of Education, Thimphu, Bhutan states that Bhutanese religious art is created in a very complementary manner. More specifically, Bhutanese religious artists spend the first five years of their training at the art school in Thimphu, learning to draw in a ritualistic way. Kelley (1987) asserts that through the use of colour and rhythm in painting these religious drawings, the artist can use his intuition and own creative expression. It is this union between Buddhist religious drawings that are nonindividualistic, with the artistic use of colour and rhythm that create a complementary relationship.

As previously stated, evidence of Niels Bohr's deep commitment to the principle of complementarity, and to the antiquity of some of its roots, is revealed by the fact that he chose the Buddhist t'ai chi drawing for his coat-of-arms when he was knighted by the Government of Denmark for his outstanding contributions to science and Danish cultural life (see Figure 2). Capra (1983) speaks of the significance of this decision in communicating the complementary relationship between Eastern and Western thought by stating that:

> In choosing this symbol for his coat-of-arms together with the inscription *Contraria sunt complementa* (Opposites are complementary), Niels Bohr acknowledged the profound harmony between ancient Eastern wisdom and modern Western science. (p. 175)

Capra (1983) continues by revealing that the yang in eastern philosophy represents the strong, male, creative power and is represented by Heaven. The yin, on

Figure 2. Niels Bohr's coat-of-arms. From *Niels Bohr* (p. 304) by S. Rozental (Ed.), 1967, Amsterdam: North-Holland. Copyright by Niels Bohr Archive. Reprinted by permission.

the other hand, symbolizes the female, dark, receptive, maternal element and is associated with the Earth. In explaining how eastern philosophers interpret the yin and yang Capra writes:

> They realize that good and bad, pleasure and pain, life and death, are not absolute experiences belonging to different categories, but are merely two sides of the same reality; extreme parts of a single whole. The awareness that all opposites are polar, and thus a unity, is seen as one of the highest aims in the spiritual traditions of the East. (p. 157)

The metaphor of complementarity as communicated intuitively by the t'ai chi symbol and rationally by the "Copenhagen Interpretation of Quantum Mechanics", may be more fully and concretely understood by turning now to the most recent research on hemispheric differences in the human brain.

The Two Complementary Modes of Knowing as Revealed by Hemispheric Differences in the Human Brain

Figure 3 represents the cerebrum, which is the largest part of the human brain. It is divided into two symmetrical halves, or hemispheres, each of which controls the opposite side of our body. "If our skulls were transparent our right and left hemispheres would appear as mirror images of each other" (Restak, 1984, p. 237).

Historically speaking, the initial research focusing on hemispheric specialization came from unilaterally brain damaged subjects who had experienced an injury or stroke which affected one of the cerebral hemispheres (Corballis, 1983). Typically, damage to the left hemisphere causes aphasia (loss of speech) and hence, is now extensively acknowledged as the predominant hemisphere for language functions (Gazzaniga, 1975). Basser, in 1962, reported that between two years and adolescence, damage to

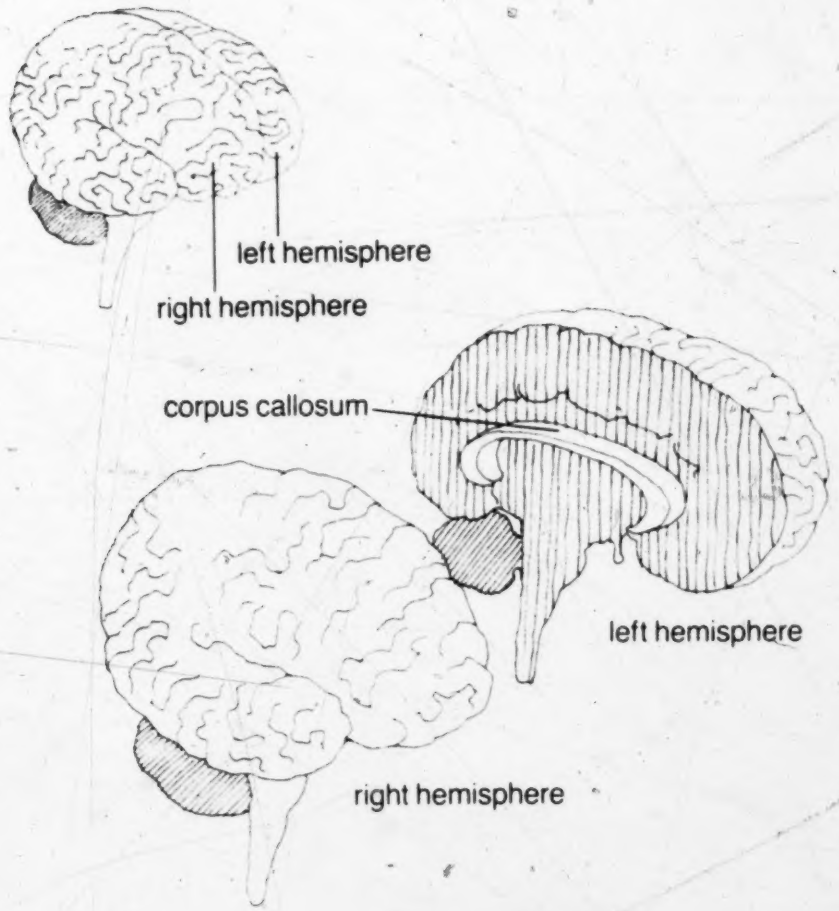

Figure 3. The cerebrum--the largest part of the human brain. From *The amazing brain* (p.12) by R. E. Ornstein, R. F. Thompson and D. Macaulay, 1984, Boston: Houghton Mifflin. Copyright 1984 by Houghton Mifflin. Reprinted by permission.

the left hemisphere has increasingly harmful effects, and damage after puberty yields essentially irreversible loss of language skills (cited in Corballis, 1983). Whereas, cerebral damage to the right hemisphere creates deficits in visuo-spatial functions. For example, a person suffering from a right hemispheric lesion may have trouble dressing himself, finding direction, and recognizing people who are familiar to him (Russell, 1979).

It is now broadly accepted that the two hemispheres have significantly different functions (Blakeslee, 1980; Bogen, 1969; Gazzaniga, 1972; Gazzaniga & Le Doux, 1978; Ornstein, 1972; Restak, 1984; Springer & Deutsch, 1981). The left hemisphere is primarily involved with analytical and logical thinking, especially in verbal and mathematical functions, and has been labelled the "major hemisphere" (Blakeslee, 1980). On the other hand, the right hemisphere has been characterized as non-verbal, arational, intuitive, spatial and has been labelled the "minor hemisphere" (Bogen & Bogen, 1969).

> In general, the left hemisphere is more important for language and certain motor skills. On the average, the right side of the brain does better with certain kinds of spatial functions such as mentally walking through a maze, understanding and working with maps, visualizing and remembering faces, and other performances that don't depend on verbal descriptions. (Restak, 1984, p. 248)

In an article entitled, *Hemispheric Specialization and Functional Plasticity During Development,* Levine (1984) further supports Restak (1984) by stating that:

> It is now widely accepted that the left hemisphere is specialized for analytic, linguistic functions while the right hemisphere is specialized for more holistic visuo-spatial and tactuo-spatial functions as well as the perception of tonal patterns and environmental sounds. (p. 78)

Consequently, a major purpose of this chapter is to delineate and to describe how the two complementary modes of knowing are reflected in the very structure and

functioning of our brains. It is the intent of this thesis to document and support the existence in human beings of two major modes of learning, of knowing: one is rational, analytical, the other, intuitive, holistic.

Turning now to the structure and functions of the cerebral hemispheres, Figure 4 depicts that the two hemispheres are connected by a ten centimeter long, pen-shaped bundle of nerve cell fibres called the corpus callosum. The corpus callosum is the largest nerve cell pathway in the brain; it is a bridge of some three hundred million nerve cell fibres (Ornstein, Thompson & Macaulay, 1984). Restak (1984) reports that the function of these fibres was once thought to be only to transport epileptic discharges from one hemisphere to the other. The reality of this situation was that incurable epileptic patients were dying because of the transfer of electrical activity from one hemisphere to the other via the corpus callosum. Then the question arose, What would happen if the corpus callosum was severed? Van Wagenen, a neurosurgeon, in the 1940s performed this surgical operation with patients of incurable epilepsey (Restak, 1984). The operations were a success in that the formerly untreatable seizures stopped and surprisingly the post analysis of these patients resulted in no observable impairment in brain function. Of course, the question was asked: What, then is the function of the corpus callosum? In response to this query Gazzaniga (1975) stated:

> The corpus callosum, the cerebral commissure that interconnects the left and right half brain, had been considered an enigma to neurologists and neurosurgeons in the 1940's and 50's. It was the structure discussed most often when an example was sought to show how little was known about the brain. Even though it is the largest nerve tract in the brain, which in man contains more than two hundred million neurons. . . . (p. 75)

Some ten years later, Roger Sperry (Nobel Laureate, 1981) and his student Ronald Myers, showed a role of the corpus callosum to be the transmission of learning

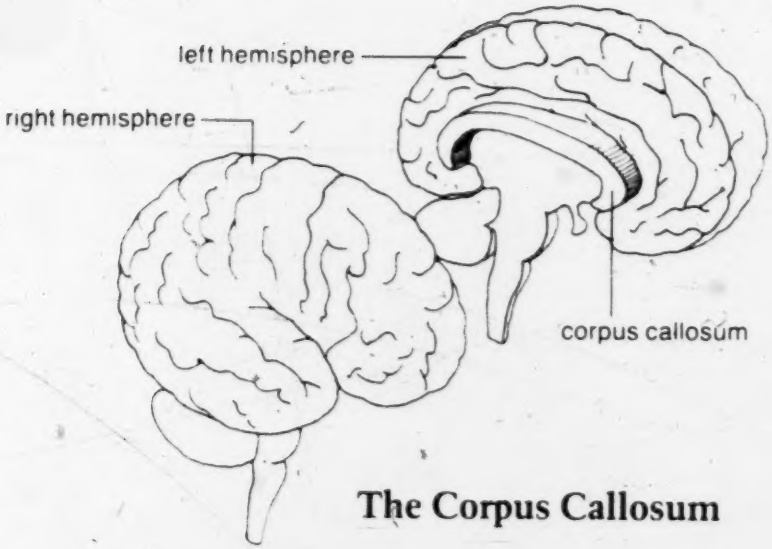

Figure 4. The corpus callosum--a bridge of some three hundred million nerve cell fibres. From *The amazing brain* (p. 34) by R. E. Ornstein, R. F. Thompson and D. Macaulay, 1984, Boston: Houghton Mifflin. Copyright 1984 by Houghton Mifflin. Reprinted by permission.

from one hemisphere to the other (Bogen and Bogen, 1969). These experiments by Myers and Sperry in the 1950s were initially done with cats and dogs and later with monkeys and chimpanzees. Their research portrayed how one could prevent interhemispheric transfer of visual information by severing the corpus callosum (Gazzaniga, 1975). This work gave birth to the now famous split-brain experiments. This operation was next performed on human beings suffering from severe epilepsy by the neurosurgeons, Joseph E. Bogen & P. J. Vogel (1962, 1965). The subsequent analysis of these patients, that had had their corpus callosum severed, was performed by Roger Sperry and his colleague Michael Gazzaniga. They discovered through their very subtle tests that the two cerebral hemispheres process information differently.

> If, for instance, the patient felt a pencil in his right hand, he could verbally describe it, as would be normal. But if the pencil was in his left hand, he could not describe it. Recall that the left hand informs the right hemisphere which does not possess any capability for speech. With the corpus callosum cut, the verbal (left) hemisphere is no longer connected to the right hemisphere which largely communicates with the right hand. If, however, the patient was offered a selection of objects--a key, book, pencil, etc.--and was asked to choose the previously given object with his left hand he could choose correctly, although he still could not state verbally just what he was doing. (cited in Ornstein, 1972, pp. 71-72)

Other tests performed on the split-brain patients tested their ability to write and draw with either hand. The skill to write English stayed with the right hand, but this hand could no longer draw very well. It seemed to have lost its ability to work in a visual-spatial manner as Michael Gazzaniga reveals:

> I showed that his right hand was unable to arrange a standard set of red and white blocks to a picture design, while the left, non-preferred hand could complete the task. . . . The claim that we based on those findings was that the left hemisphere is dominant for the language processes and the right hemisphere is dominant for visual constructional tasks. (cited in Restak, 1984, p. 248)

Further research with subjects suffering from chronic epilepsey has been conducted by use of the sodium amytal test, which was developed by J. A. Wada and T. Rasmussen in 1960. This test is considered to be very reliable for assessing cerebral lateralization for speech (Corballis, 1983). By injecting sodium amytal into the carotid artery on one side of the neck, it is possible to completely anesthetize the hemisphere on that same side of the brain (Russell, 1979).

Corballis (1983) points out that studies which have utilized this technique have consistently found that when the left hemisphere was suppressed, subjects showed a marked decrease in being able to verbalize their responses to questions. Additionally, Harris (1979) states that results of the Wada test have revealed that over 95% of right-handed patients have their speech centre in the left hemisphere. In the left handed (approximately 5% of the general population) and those which are ambidexterous, 70% have the speech center in the left hemisphere. While in the remaining 30% (which is 2% to 3% of the general population) half have their speech centre in the right hemisphere and half seem to have speech centers in both.

In another study by Gordon and Bogen (1974) involving sodium amytal, it was found that after right carotid injection, singing was markedly deficient, whereas speech remained relatively intact. Songs were sung in a monotone manner, lacking any form of proper pitch; however, rhythm was much less affected. In contrast, singing was much less disrupted as compared to speech after left carotid injection. The authors concluded that the left hemisphere displayed its usual dominance for speech while the right hemisphere contributed more to the behavior of singing.

Research has also been conducted with "normal" subjects and has helped to dismiss the criticisms of the initial findings which were predominantly with epileptic

patients. Hampden-Turner (1981) reports that the recent brain research on hemispheric lateralization makes use of EEG (electroencephalogram) recordings which report the degree of electrical discharge from brain cells. These studies reveal that there is an increase in alpha rhythm in whichever hemisphere is resting, together with electrical activity in the hemisphere that is processing the information.

An example of this type of study was conducted by Galin and Ornstein in 1972 at the University of California Medical Centre (Blakeslee, 1980). The experiment was performed with six normal subjects which involved a left-brain task of writing facts from a newspaper article that had been read previously. The right hemispheric function consisted of constructing a visual pattern just memorized from a group of multi-colored blocks. The results revealed that all subjects displayed an increase in alpha waves in the left hemisphere when they were performing their visual-spatial tasks. It is important to remember that an increase in alpha rhythm means that that part of the brain is resting or "idling." Hence, it appears that if you ask someone a verbal problem the left hemisphere begins to "fire" and if you present a visual-spatial problem to someone then the right hemisphere displays less alpha wave activity than the left. Similiarly, Osborne and Gale (1976) monitored the EEG's of the right and left hemispheres of 21 subjects, ranging in age from 21-50 years, while the subjects were presented with words, music and arithmetic problems. They discovered that the left hemisphere of the brain was activated during presentation of words and arithmetic problems, while the right side of the brain was most activated during the presentation of music.

Bakan (1969) also reports experimental evidence in which lateral eye-movements (LEM) correlate with hemispheric specialization. That is, the eyes will typically move away from the more engaged hemisphere towards that side of the body

controlled by that hemisphere; so that a professor rising to present her lecture will glance to her right, and a dancer rising to his toes will glance left. In the Bakan study this hypothesis was confirmed by having the subjects interpret proverbs, provide simple definitions and do simple arithmetic problems which all would supposedly engage the left hemisphere. Questions involving visualization like (How many edges are there on a cube?) and musical skills (recognizing piano melodies) were used to activate the right hemisphere (Springer & Deutsch, 1981). The results portrayed that subjects whose left hemisphere was activated by the verbal questions initially always glanced to the right and subjects whose right hemisphere was activated by the visual-spatial problems glanced to the left. Furthermore, Weiten and Etaugh (1974), in a study focusing on the relationship between lateral eye-movements and musical and mathematical problem solving, asked 39 college and high school students to solve arithmetic problems and identify melodies. It was found that more lateral eye-movements were made to the right on arithmetic questions than on musical ones. The authors concluded that their findings were consistent with previous research.

Research on hemispheric specialization has also been conducted through the use of dichotic listening. In this technique the subject listens through stereophonic earphones to auditory stimuli, with different stimuli presented simultaneously to the ears. The stimuli may be verbal, such as words or phonemes, or nonverbal, such as musical notes or melodies. In general, studies of this nature with adults reveal a right ear (left hemisphere) superiority for verbal material and a left ear (right hemisphere) superiority for nonverbal stimuli (Harris, 1979). An example of a study that has used the dichotic listening technique follows.

Borod and Goodglass (1980) examined the effect of aging on hemispheric specialization for verbal and melodic materials using dichotic listening as an index of measurement. One hundred and two right-handed males aged 24-79 years were tested on two occasions. While overall scores declined with age, there was no interaction between age and the degree of right ear (left hemisphere) advantage for verbal material and left ear (right hemisphere) advantage for melodies.

In summary, literature reviews focusing on the functions of the right and left hemispheres have been consistent in their conclusions. Cassel (1978) in an article entitled *Split Brain Functioning*, states that:

> For the most part the left side of man's brain is the only side one retains consciousness with and is the side related to speech and verbal functioning. It is referred to as the dominant side because much of man's problem solving and reasoning takes place there. The right side is the non-dominant side, and it deals with perceptions of one's environment; music, art, geometry, and the aesthetics. (p. 2)

Harris (1979) in an article focusing on previous studies dealing with lateral dominance and reading disability asserts that:

> Direct measures of cerebral hemisphere functioning indicate that the left hemisphere is dominant for speech, sequential processing, and logical thinking in nearly all right-handers and the majority of left-handers, while the right hemisphere is dominant for holistic or Gestalt perception, nonverbal reasoning, and music. (p. 57)

Finally, Rubenzer (1979) while reviewing literature specific to the functions of the right hemisphere concludes:

> The right hemisphere is more involved than the left hemisphere with the interpretation and retention of complex non-verbal, visual and auditory patterns such as the recognition of facial features or recall of melodic patterns. The right hemisphere is predominant in processing the "artistic subjects" (music, art, dance and physical education) and is theorized to be most adroit at processing tasks that require simultaneous and divergent cognitive styles. (p. 90)

It is important to state before proceeding that the brain operates as a whole and we may speak of specific modes of functioning but the oneness of this organ must not be overlooked (Fishburne, 1984; Ornstein, Thompson & Macaulay, 1984; Restak, 1984). Moreover, and most recently, what has emerged in the theory of hemispheric specialization is the conception that the cerebral hemispheres function in a complementary manner (Capra, 1983; Levine, 1984; Ornstein, Thompson & Macaulay, 1984). Rather than viewing one hemisphere as being major or minor as in the theory of cerebral dominance, scholars are proposing that the intuitive, holistic thinking right hemisphere complements the analytical, linear processing left hemisphere, in our perception of the world (see Figure 5).

Educating the Whole Brain

Bogen (1975) states that learning of any attitude, concept or skill is likely to be better if both hemispheres or the two complementary modes of thought processing are used. He warns us against an elementary school curriculum that stresses the three "Rs" only: "Since education is effective only in so far as it affects the working of the brain, we can see that an elementary school program narrowly restricted to reading, writing and arithmetic will educate mainly one hemisphere, leaving half of the individual's high level potential unschooled" (p. 27).

The subject areas of art, dance, drama, music and physical education are de-emphasized within the elementary school curriculum of Canada as well as Bhutan. In an article by Fishburne (1983), entitled: "Is Reading More Important than Physical

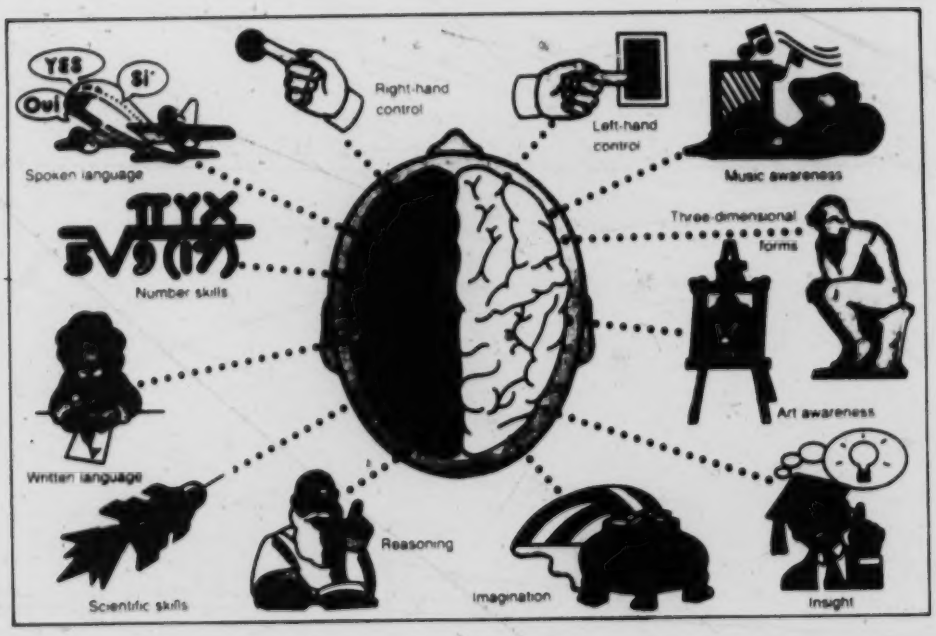

Figure 5. The complementary functions of the brain's two hemispheres. From *The Brain: Mystery of matter and mind* (p. 32) by J. Fincher, 1984, New York: Torstar Books. Copyright Marshall Editions. Reprinted by permission.

Education?", the author raises the ultimate question of values and its relation to the elementary school curriculum in Alberta, Canada. Fishburne, poses questions similar to these: Are interpersonal skills more important than music? Is language arts more meaningful to our children than physical education? Is mathematics education more life enhancing than art? By revealing Alberta Education's recommended percentage of time given to specific subject areas in the elementary schools of that province, Fishburne illustrates the reality of answers to these questions. The reader is referred to Table 1 for a depiction of these value judgements.

Fishburne (1983), a keen proponent of the benefits of physical education, cites a longitudinal study which was conducted in France from 1951 to 1960. A summary of the conclusions made by Fishburne, for this nine year study, of children participating in physical activity for at least 33% of their school day, follows.

> 1. Doctors and educators in France now think alike--physical education is an integral part of education, perhaps even the main part.
>
> 2. Scientific research into the effects of physical education established the following:
>
> a. it promoted the growth of children;
> b. those taking physical education had better health;
> c. motor development was improved, and was better balanced;
> d. those taking physical education had superior performance academically and less susceptibility to stress.
>
> 3. The study between the experimental and control groups showed:
>
> a. the 1/3 time physical education pupils matured more quickly, and were more independent;
> b. the physical education groups accept the social way of life better; that is, by playing with and against others in a physical setting, children learn the "life game" better than those who did not participate;
> c. Aggressions can be controlled more effectively through physical education opportunities. (p. 19)

The importance of physical activity to children is also very evident in the elementary schools of Bhutan. Turner and Turner (1985b) initially visited Bhutan in

TABLE 1

Allotment of subject time for grades one and two (Division 1) and grades three through six (Division 2) of Alberta Elementary Schools.

Subject	Division 1 (in %)	Division 2 (in %)
Language Arts	35	30
Mathematics	13	13
Social Studies	7	10
Science	5	7
Music	5	5
Art	5	5
Physical Education	6	6
Health	4	4
Undefined	20	20

Note. From *Program of studies for elementary schools* (p. viii) by Alberta Education, 1982, Edmonton: Curriculum Policies Board of Alberta Education. Copyright 1982 by Alberta Education. Adapted by permission.

July of 1985 in order to explore the feasibility of this present research and to undertake a primary education curriculum development assignment. They were amazed at how well the Bhutanese children spoke English, the language of instruction, in the schools they visited. Turner and Turner (1985b) inferred that this language development was a result of the children's extensive participation in musical games, rhymes and action songs emphasized during their first few years of schooling and continued in their everyday life. However, they were asked, by an official of the Bhutan Board of Examinations, how to stop these musically oriented physical activities at an earlier age without causing abrupt change in the schooling of these children. The rationale behind such a request was based upon the belief that there was little educational benefit in these musical activities.

This attitude, which appears to be prevalent in all parts of the world, displays a lack of understanding with regard to the function of the right hemisphere in learning, as Sperry (1983) affirms:

> What I am getting to is that these developments regarding the right hemisphere seem to tell us among other things, that our educational system and modern society generally (with its very heavy emphasis on communication and on early training of the three R's) discriminates against one whole half of the brain. I refer, of course, to the non-verbal, nonmathematical, minor hemisphere, which we find has its own perceptual, mechanical and spatial mode of apprehension and reasoning. In our present school system, the minor hemisphere of the brain gets only the barest minimum of formal training, essentially nothing compared to the things we do to train the left or major hemisphere. (p. 59)

What becomes so evident from research on the split-brain is the significance and vital importance of an elementary school system for children that emphasizes the education of the whole brain. If we, as educators, continue to emphasize the verbal, logical, analytical mode of thought in our elementary schools at the expense of the non-

verbal, artistic, intuitive mode then we will surely continue to produce imbalanced people (Bogen, 1975).

Blakeslee (1980) cautions curriculum developers in their recent trend to eliminate art, dance, drama, music and physical education from the elementary school curriculum because of the extreme importance of these subjects in the development of non-verbal thinking and intuitive reasoning. It is these activities that allow young children to explore and understand their environment in the first five years of life and we should continue to promote these natural activities throughout schooling alongside the verbal-analytical approach. Blakeslee declares that "Man's highest achievements are a result of using the full power of *both halves* of the brain together" (p. 74).

The irony of the emphasis on the three Rs in the school systems throughout the world, is even further deepened when one reads the words of Albert Einstein when he speaks of his own creative thought processes.

> The words or the language as they are written or spoken, do not seem to play any role in my mechanism of thought. The psychical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be "voluntarily" reproduced and combined. . . . The above mentioned elements are in my case of visual and some of *muscular type* [italics added]. Conventional words or other signs have to be sought for laboriously only in a secondary stage. . . . (cited in Hadamard, 1945, pp. 142-143)

It is obvious that Einstein was aware of the use of his right hemisphere in his own creative thinking, as well as the left in completing the last phase of recording symbolically his visual and muscular images. It is here that we see the vital role of the corpus callosum in transmitting information between the hemispheres, and revealing the oneness of the organ. For without this transmission, the images conceived would remain stagnant within the creator's mind.

Concluding Remarks

The fundamental theoretical formulation proposed by this thesis, is that in order to fully understand the world in which we live, in other words the nature of living systems, we must utilize the two complementary modes of knowing. Roger Bacon asserted over 700 years ago, "There are two modes of knowing, those of argument and experience" (cited in Ornstein, 1972, p. 12). Ornstein continues:

> They are complementary to one another; neither is reducible to the other and their simultaneous working may be incompatible. One mode is verbal and rational, sequential in operation, orderly; the other, less logical and neat, a mode we often devalue, culturally, personally and even physiologically. (p. 12)

The two modes of operation complement each other, but do not replace one another. Consider attempting to verbally encode each bodily movement while swimming the front crawl; or contemplate trying to learn how to ride a bicycle solely from a verbal description.

Perhaps the following contemporary folklore stories, created by the author Idries Shah, about "a thinker from the East" named Mulla Nasrudin, may intuitively communicate the intent of this thesis.

Never Know When It Might Come in Useful

> Nasrudin sometimes took people for trips on his boat. One day a pedagogue hired him to ferry him across a very wide river. As soon as they were afloat, the scholar asked whether it was going to be rough.
>
> "Don't ask me nothing about it," said Nasrudin.
>
> "Have you never studied grammar?"
>
> "No," said the Mulla
>
> "In that case, half your life has been wasted."
>
> The Mulla said nothing.
>
> Soon a terrible storm blew up. The Mulla's crazy cockleshell was filling with water. He leaned over his companion. "Have you learned to swim?"
>
> "No," said the pedant.

"In that case, schoolmaster, all your life is lost, for we are sinking." (cited in Ornstein, 1972, p. 65)

Moment in Time

"What is Fate?" Nasrudin was asked by a scholar.
"An endless succession of intertwined events, each influencing the other."
"That is hardly a satisfactory answer. I believe in cause and effect."
"Very well," said the Mulla, "look at that."
He pointed to a procession passing in the street. "That man is being taken to be hanged. Is that because someone gave him a silver piece and enabled him to buy the knife with which he committed the murder; or because someone saw him do it; or because nobody stopped him?" (Shah, 1966, p. 21)

Finally, it has been the goal of this chapter to lay the theoretical foundation for complementarity as the basis for an extension of epistemology. The Nobel laureate, Niels Bohr firmly believed in this conception, and proposed that one day complementarity would be taught in schools and become part of public education (Holton, 1973).

From antiquity to the present date, it has been shown that there are two complementary modes of knowing which have been most strongly revealed through the study of science and religion. Recently, these two complementary modes of knowing have been given further validity by contemporary research on hemispheric specialization of the human brain. Our brain is structured and functions in a complementary manner, our brain is structured and functions as a whole.

CHAPTER THREE

BHUTAN: EDUCATION AND ETHNOMATHEMATICS

The Himalayan Kingdom of Bhutan is a small landlocked country having an area of 46,500 square kilometers (about the size of Nova Scotia). It is bordered by China (Tibet) to the north and by India, its most influential neighbour, to the south, east and west. The terrain is some of the most rugged in the world, rising from altitudes close to sea level to the peaks of the Jumolhari which reach upwards to over 7,000 meters. The country is characterized by hills that stretch from the plains to the Himalayas, and which are severed by river valleys that usually run from north to south. It is this combination of remote location, rugged terrain and natural borders joined with a strong sense of identity and independence, that has enabled Bhutan to remain relatively isolated from the outside world for over 300 years (Pemala, 1983; Scofield, 1976).

The country has limited natural resources and for most products there are markets in neighbouring countries such as India and Bangladesh. Bhutan's location on the steep northern side of the Himalayas provides it with excellent hydroelectric potential which is just beginning to be tapped. Bhutan's other major natural resource is its forests which cover approximately two-thirds of the land area. Presently, forest extraction is only a small fraction of the annual forest increment and some of the forest is decaying from overage. Bhutan also has deposits of certain minerals, including limestone, dolomite, graphite, lead, gypsum, coal and zinc, but for the most part these

mineral deposits are inaccessible and detailed surveys have yet to be undertaken (Strydonck, Pommaret-Imaeda & Imaeda, 1984).

The total population of Bhutan is estimated to be 1,165,000 and is made up of a mosaic of varied peoples which up to the present day have lived in valleys isolated from one another because of the formidable mountain passes. The northern region, over 3000 meters above sea level, is sparsely inhabited when compared to the lower central and southern regions. The population is generally classified into three major ethnic groups: the Sharchops, the Ngalops and the Nepalese. The Sharchops, thought to be the earliest inhabitants of Bhutan, live primarily in the east and are of Indo-mongoloid origin. The Ngalops are believed to be of Tibetan origin and settled in Bhutan during the 8th century. They brought with them their culture and Buddhist religion which characterizes the north-western section of this country today. The Nepalese, most of whom are Hindus, arrived in the country at the end of the 19th century to farm the foothills of the south (United Nations Development Programme, 1985).

Strydonck, Pommaret-Imaeda and Imaeda (1984) indicate that the official language of Bhutan is Dzongkha which is closely related to classical Tibetan. They state:

> The five valleys which make up western Bhutan are where *Dzongkha*, the "language of the Dzong (fortress)" is spoken. It has become the official language of Bhutan. Although similar to Tibetan, it has many differences especially in the pronunciation and conjugation of verbs. (p. 12)

In southern Bhutan Nepali predominates as does Sharchops in the east, furthermore, there are as many as eleven other different vernacular languages. As a result of this, and in order to facilitate contact with the outside world, English has become the medium of instruction within the schools.

Bhutan is classified as a constitutional monarchy. His Majesty, King Jigme Singye Wangchuck was crowned on June 2, 1974 at the age of 18 and became the fourth hereditary King of Drukyul, the Land of the Peaceful Dragon (Scofield, 1974). The spiritual head of Bhutan, the Je Khempo, is the only person in addition to the King, who wears the saffron scarf, revealing his authority over all religious institutions.

Pemala (1983) points out that the modern history of Bhutan begins with the advent of Buddhism in the country during the middle 7th century when Jampa Lhakhang in Bumtang and the Kichu Lhakhang in Paro were constructed. These religious temples are considered to be the oldest Buddhist temples in the country. Since that time Buddhism has played a major role in shaping the course of Bhutan's history which is revealed by the fact that the names of the country, Drukyul, and of its inhabitants, Drukpa, are derived from the Mahayana Buddhist school, Drukpa Kagyupa. The omnipresence of Buddhism within the lives of the Bhutanese is vividly expressed in the following words by Rigzin Dorji (1983b):

> Religion may justifiably be called the fountain-head of Bhutanese culture. Not only does it exert a pervasive influence in Bhutanese society, but almost every single facet of life in the country draws inspiration from it. From archery contests to the painting of murals, from the phenomenon of birth to that of sickness and death, almost each significant moment in the life of a Bhutanese is, in one way or another, linked with religion. (p. 40)

It is important to reiterate at this time, that Bhutan is the only independent nation of the world where Mahayana Buddhism is the State religion (Strydonck, Pommaret-Imaeda & Imaeda, 1984).

Administratively, the country is divided into 18 districts called *dzongkhags*. There are three such dzongkhags in eastern Bhutan, three in the south, five in central

Bhutan and seven in the western region. Each district is overseen by an official named a *dzongda* who is appointed by the King. Although village headmen usually settle disputes, district judges or *thrimpons* supervise the courts in each of the 18 dzongkhags.

Development and the Significance of Education

The United Nations classifies Bhutan as one of the thirty-one least developed countries in the World having an estimated per capita income of U. S. $116.00 per year. Approximately 95% of the people are agrarian being mainly involved with subsistence farming and animal husbandry. Since the ratio of people to land is 25 per square kilometer, landlessness is not a problem and farmland is generally equally-distributed. Maize is the major foodgrain and other principle crops include barley, buckwheat, mustard, oilseeds, potatoes, peppers, pulses, rice and wheat. Recently, apples, asparagus, cardamom, ginger, mushrooms, oranges, potatoes, and tropical fruits have emerged as significant cash crops.

In an effort to expand its economy from one solely based on agriculture and cattle rearing, Bhutan in 1961, initiated a series of five-year-plans. The major goal of these plans has been to create a structural transformation in the socioeconomic system, and more concisely to change a barter system into a modern economy. Consequently, in 1968 the Bank of Bhutan was created and in 1982, the Royal Monetary Authority, whose function is that of a central bank, was founded.

Economic development also involves improvement in means of communication, which is especially true for Bhutan as there are no railways and it was not until 1983

that one could reach Bhutan other than by road. In February of that year, Bhutan's official airline, "Druk Air" was inaugurated and an air link between Calcutta, India and Paro, Bhutan was created. More recently, Bhutan has strengthened its ties with Bangladesh, and established a further air passage between Dhaka, the capital of Bangladesh and Paro. Bhutan has a intricate network of mule paths which are the only means of access to many areas of the country. The road system has expanded immensely since 1961 and by 1983 there were two thousand kilometers of roads connecting areas mainly in the southern and central regions.

A regular postal service was initiated in 1962 and a telephone, telegraph and radio network links Bhutan to the rest of the world, as well as connecting different districts within the nation. However, these intra-country communication mediums still remain somewhat unreliable.

Education has also been designated by the Royal Government of Bhutan as a major focus for further development (Strydonck, Pommaret-Imaeda & Imaeda, 1984). Education in Bhutan before the 1960s was mainly for a male population. Some boys would have had the opportunity to attend a Buddhist monastery while a few children, whose parents could afford the expense, were sent to India for formal schooling (Hasrat, 1980).

During the past twenty-five years, Bhutan has grown tremendously in all areas of development with education being no exception. As previously mentioned the government of Bhutan has initiated a series of five-year plans for the growth of the country and the fifth five-year plan (1981/82-1986/87) was aimed at creating a more solid educational foundation. More specifically, the fifth plan differs substantially from previous plans in that rather than expanding educational infrastructure, it aims at

improving existing programs and facilities by: (a) enhancing the quality of education through curriculum reform, (b) upgrading teacher training programs, and (c) reorganizing technical education (United Nations Development Programme, 1985).

An example of this educational reform at the primary school level started in the spring of 1985 when the Department of Education began planning for the implementation of a different approach in the pedagogy of a new primary school curriculum. It is important to note at this time that Bhutan's primary education system is made up of one year of kindergarten followed by six years of formal schooling. However, this categorization was only implemented in March of 1987, as before that date children undertook two years of kindergarten before proceeding onward. Today primary schools in the country number 149--still a far cry from the number needed to house all school aged children. It is reported that only 25% of the primary aged population were enrolled in schools in 1987 and this reflects the low literacy rate of 23% for this country. The literacy level and the number of children attending primary school form the lowest levels in the south Asia region and are among the lowest in the world (Department of Education, Royal Government of Bhutan, 1988).

The reasons for this low literacy level and the small percentage of school age children attending primary school are multiple but among the main ones are: (a) the location and shortage of primary school facilities, (b) the lack of adequately trained teachers, (c) the values of parents, (d) the examination system, and (e) the need for a relevant curriculum. The location of many primary schools creates a long distance between children's homes and their nearest school. Consequently, children cannot walk daily to and from school and must become boarding students at schools where latrine facilities are usually not present. Secondly, as indicated in (b) above, in 1984 of

the 428 primary teachers within Bhutan, 42% were untrained. This situation is further compounded by the fact that 36% of the primary teachers within the country are expatriates from India who are primarily secondary school specialists. Thirdly, and as aforementioned, 95% of the Bhutanese people are agrarian and thus once a child reaches a certain age he or she is able to work to help the family. Education is considered to be unnecessary or undesirable. Fourthly, up until March of 1986, primary students encountered national examinations at the end of grades three and five, and this resulted in a significant number of dropouts and repeaters. Lastly, need for a relevant curriculum has been addressed through the New Approach to Primary Education (NAPE), and it is anticipated that this new curriculum will be implemented nationwide in 1990 (Beynon & De Spiegeleer, 1985; Department of Education, Royal Government of Bhutan, 1988; Turner,1988b).

In order to combat these problems, the Royal Government of Bhutan through its fifth five-year plan, began to implement a different approach in the pedagogy of a new primary school curriculum. This educational change was spearheaded by Father W. J. Mackey, a Canadian Jesuit priest who has been in Bhutan for over twenty years, and who is presently the Chief Inspector of Schools.

In the spring of 1985, on behalf of the government of Bhutan, Father Mackey requested two curriculum consultants in the fields of English and Mathematics through the World University Service of Canada (WUSC) and consequently, this investigator came to Bhutan for the purpose of ascertaining the feasibility of conducting this research and to undertake an eight week primary school curriculum development assignment.

At that time the new primary school curriculum was introduced under the title of the environmental studies approach (EVS) and was initially implemented in 12 pilot schools beginning in February of 1986. The EVS approach places the child at the centre of learning and the child's immediate environment becomes the focus, and the stimulus for all subject matter that is studied.

This EVS approach to primary education has its foundation in South Asia at the National Council of Educational Research and Training (NCERT), New Delhi, India. B. Sharam (1981) the director of NCERT states:

> Since environmental studies is not a content area but an approach to learning, the basic idea here is to teach the information-gathering skills rather than delivering a large amount of scientific facts which children may not be able to grasp or imbibe but still spill on the examination paper as undigested pieces of information. (p. 2)

This integrated, holistic approach focuses on the child's development of skills, concepts and attitudes and attempts to abolish the study of specific subject areas.

This new curriculum project within the primary education system of Bhutan is now entitled the New Approach to Primary Education (NAPE). There was confusion between the study of Environmental Studies as a subject and as a pedagogical approach; hence in April of 1986 a decision was made by the Department of Education to change the title of the pilot project (Turner, 1988b).

The responsibility for the inservicing and education of present and future primary school teachers in this new pedagogical approach rests with the two teacher training institutions in the country: the National Institute of Education (NIE), Samchi; and the Teachers' Training Centre and Demonstration School (TTC/DS), Paro.

In order to educate prospective primary teachers in a more standardized manner, and to complement the curriculum changes occurring within Bhutan's primary

education system, NIE and TTC/DS jointly planned and implemented the same primary teacher education curriculum in July of 1986. This core curriculum is outlined in the document *Primary Teacher Certificate Course: NIE, Samchi and TTC, Paro, July 1985*.

The New Primary Teacher Education Curriculum and the Concept of Ethnomathematics

The *Primary Teacher Certificate Course: NIE, Samchi and TTC, Paro, July, 1985* contains detailed syllabi for the "teaching subjects" which include: Dzongkha (the national language); Nepali (the language of southern Bhutan); English (the language of instruction); Environmental Studies; and Mathematics. As well, the syllabi for the following "professional subjects" include: Child Study; Health, Physical Education and Sports; Practice Teaching; Principles and Practice of Education; Teaching Aids/Arts and Crafts; and Teaching Skills.

Within the Health, Physical Educatioh and Sports syllabus, one of the objectives for prospective primary school teachers is to "identify and make a program of the appropriate physical activities necessary for developing gross and fine motor skills in primary children" (p. 30). Fishburne (1985) supports this by stating:

> The importance of early learning experiences in all aspects of human movement is fundamental to the development of a child. Only by providing a rich experience of movement situations through which children can develop both motor abilities and motor skills can we, as educators, hope to develop children to their maximum potential. (p. 15)

In addition, within the Mathematics syllabus under the section entitled "Activities for Maths Teaching" the following is stated:

> (b) Outdoor Activities: how to modify outdoor activities learnt in pedagogy for the teaching of maths. The following activities will be dealt with: e.g. sandplay, mudplay, stoneplay, rhythm and movement, circle games, running games, throw and target games.
> (c) How to modify popular children's games for the teaching of mathematics. The following games will be dealt with: e.g. marble games, archery, khuru, dego, stone games. There are double purposes to these activities: (i) to develop motor skills and muscle coordination; (ii) to learn mathematics through the playway method. (p. 59)

The aforementioned reflects wisdom and insight by the Bhutanese primary school educators in the value of play to children. As Plato in the year 380 B. C. stated:

> Lessons have been invented for the merest infants to learn, by way of play and fun. . . . Moreover by way of play, the teachers mix together (objects) adapting the rules of arithmetic to play. (cited in Ashlock & Humphrey, 1976, p. 53)

Hence by utilizing activities that children naturally and spontaneously participate in, these educators are tapping the child's vital source of motivation: interest. For once a child's interest has been captured, then learning becomes a fundamental and meaningful experience (Neill, 1960). Ashlock and Humphrey (1976), the authors of what is probably the only book that deals specifically with the teaching of elementary school mathematics through motor activity, concur by stating:

> A good condition for learning is a situation in which a child agrees with the learning which he considers of most value to him, i.e. those that are of greatest interest to him. To the very large majority of children, their active play experiences are of the greatest value to them. (p. 31)

These authors would refer to the section "Activities for Maths Teaching" in the Bhutanese teacher trainer syllabus, as teaching elementary school mathematics through the medium of physical education. Humphrey, and his colleagues, who have done extensive research on the teaching of elementary school subjects through motor activity report that this branch of motor learning is concerned specifically with children learning basic skills and concepts in elementary school subjects through the medium of motor

activity (Ashlock and Humphrey, 1976; Humphrey, 1974; Humphrey, 1975a; Humphrey, 1975b; Humphrey, 1976; Humphrey, 1987; Sullivan & Humphrey, 1973). Humphrey (1974, 1987) theorizes that because children are predominantly movement oriented, they will learn more efficiently when physical activity operates at a maximum level in a school subject like mathematics.

Ashlock and Humphrey (1976) disclose that the "motor activity learning medium" has the added dimension of improving learning through kinesthetic feedback:

> The motor activity learning medium provides almost instantaneous knowledge of results because the child can actually *see* and *feel* [italics added] himself throw a ball, or tag, or be tagged in a game. He does not become the victim of a feedback mechanism in the form of a poorly constructed paper and pencil test, the results of which may have little or no meaning for him. (p. 32)

Bilodeau and Bilodeau (1961) further report that knowledge of results is the strongest most important variable controlling motor performance and motor learning. They reveal that there is gradual improvement with feedback, no improvement without it, and deterioration if it is completely withdrawn.

The significance of kinesthetic feedback is also reported by Steinhaus (1966). He states:

> A larger portion of the nervous system is devoted to receiving and integrating sensory input originating in the muscles and joint structures than is devoted to the eye and ear combined. (p. 38)

As a result of this discovery, Steinhaus proclaims that man is "muscle-sense minded".

By recommending that children learn mathematics through such physical activities as: sandplay, mudplay, stoneplay, rhythm and movement, circle games, running games, target games, marble games, as well as, archery, khuru and dego; the Bhutanese are suggesting that children can and should learn mathematics through an ethnomathematical medium.

The Brazilian mathematics educator, Ubiratan D'Ambrosio has been credited with coining the term "ethnomathematics" (Scott, 1985). By this concept, he depicts the influence that sociocultural factors have on children learning and being taught mathematics.

The prefix *ethno* refers to "identifiable cultural groups, such as national-tribal societies, labor groups, *children of a certain age bracket*, [italics added] professional classes, and so on" (D'Ambrosio, 1985, p. 44). As well, the concept of ethno includes the jargon, codes, symbols, myths and specific ways that these identifiable cultural groups have in reasoning and inferring (D'Ambrosio, 1985; Scott, 1985).

The conceptualization of mathematics within the term ethnomathematics focuses on the practices of *counting*, *ordering*, *sorting*, *measuring* and *weighing* and how identifiable cultural groups go about these tasks (Lancy, 1983; Wilder, 1981). D'Ambrosio (1985) discloses that anthropologists have depicted cultural groups that perform these mathematical tasks in strikingly different ways than are traditionally taught in the school system.

To summarize, Scott (1985) defines ethnomathematics as the following:

> Ethnomathematics lies at the confluence of mathematics and cultural anthropology. At one level, it is what might be called "math in the environment" or "math in the community". At another, related level, ethnomathematics is the particular (and perhaps peculiar) way of classifying, ordering, counting and measuring [and weighing]. (p. 2)

Therefore, the direct relevance of ethnomathematics to this research is characterized by how the play and motor activities of the elementary school children of Bhutan (the identifiable cultural group) exhibit the mathematical practices of counting, ordering, sorting, measuring and weighing.

D'Ambrosio (1981), whose major research interest is in the development of a holistic, integrated approach to mathematical education in the Third World, proposes a model by which we can more fully comprehend the lives of children and their awareness of mathematics. To gain a deeper understanding of this model, which is diagrammatically illustrated in Figure 6, let us focus on the *reality* of a boy's life in Bhutan as he participates in a game of archery, the national sport.

In archery, counting is present, in keeping record of the score in the contest, for example. Each team has a certain number of players who in a specific order will shoot two arrows at the target which has been measured to be 130 meters away. Also, the young archer must sort the bamboo wood into different categories before the arrow is made. Finally, the arrowhead must be of a particular weight as this will significantly affect the flight of the arrow through space.

As well, other play and motor activities of Bhutanese children contain these five basic mathematical practices. As a child "putts the shot" (a stone) he has stereognostically measured the weight before attempting to project this object through space. (Stereognostic refers to the perception of the shape and weight of an object through the tactile and kinesthetic modality.) How far did the stone travel? The young elementary school girls in Bhutan love to skip--so many times on one foot, so many times on the other, with a rope of a certain length, . . . with how many friends!

Strydonck, Pommaret-Imaeda and Imaeda (1984) make known that football (soccer) is quickly becoming the most popular sport in Bhutan. When visiting Bhutan in the summer of 1985, the author observed that football was by far the most common game played by the young boys in Thimphu, the capital city. Everywhere, elementary school boys were kicking and chasing balls of all sizes in any open area they could

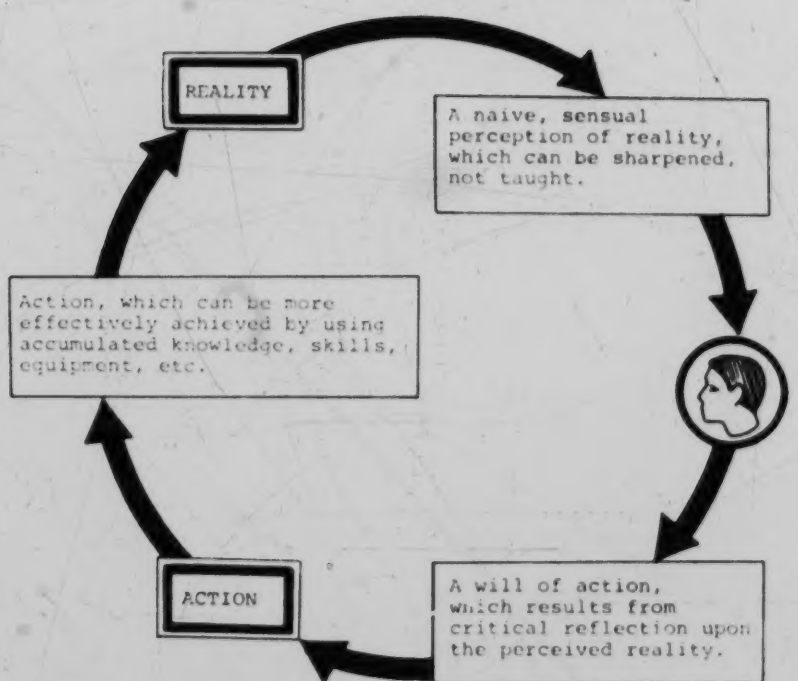
REALITY
A naive, sensual perception of reality, which can be sharpened, not taught.
A will of action, which results from critical reflection upon the perceived reality.
ACTION
Action, which can be more effectively achieved by using accumulated knowledge, skills, equipment, etc.

Figure 6. A model for a child's understanding of reality. From "Uniting reality and action: A holistic approach to mathematics education." by U. D'Ambrosio, 1981. In L. A. Steen and D. J. Albers (Eds.), *Teaching teachers, teaching students* (p. 39). Boston: Birkhauser. Copyright 1981 by Birkhauser. Adapted by permission.

find. If we analyze football through the above mathematical practices, questions arise such as: How many players are on Uygen's team? What position will he play on the field? Where are his fellow teammates located? How long is the field? How wide? What area does it cover? How heavy is the ball, what is its diameter, circumference, volume, radius? As one can imagine, the interpretation of football (the most played and watched worldwide sport) through the mathematical practices of counting, sorting, measuring and weighing can lead to a mathematical state of infinity!

It is an hypothesis of this research that the above mathematical practices, characteristic of ethnomathematics, are inherent within the songs, games, and movement of elementary school children in Bhutan. Hence, as D'Ambrosio (1981) points out, teachers must adopt a different approach in the holistic education of children in the developing world; that is, to assist the child in his or her perception of reality. He asserts:

> Teachers and schools must play a new role in holistic education . . . the teacher must intervene in the process of learning by stimulating critical reflection by the student upon his perceived reality which as a result will sharpen his capability to perceive reality. (pp. 39-40)

Also D'Ambrosio (1981) states that the education of teachers requires a significant change (see Figure 7). He declares:

> It is not the teacher's knowledge or skill that will determine his effectiveness, but rather his ability to sense children's perception of reality and children's drive toward action. Of course, mathematics does not escape from this scene. Either mathematics fits into the context in which the individual functions, or mathematics will be an appendix to the educational experience, rather a "useless appendix" using the phrase popularized by H. B. Griffiths and A. G. Howson. (pp. 40-41)

In this research the action for the child becomes his or her play and motor activities. Thus, this investigation will heed the advice of Plato who wrote in

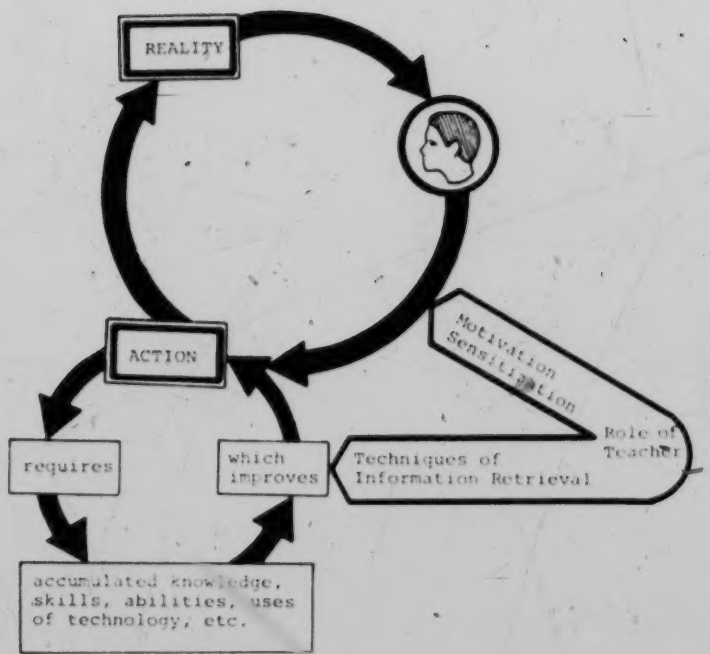

Figure 7. The new role of the teacher in the education of children in the developing world. From "Uniting reality and action: A holistic approach to mathematics education." by U. D'Ambrosio, 1981. In L. A. Steen and D. J. Albers (Eds.) *Teaching teachers, teaching students* (p. 40). Boston: Birkhauser. Copyright 1981 by Birkhauser. Adapted by permission.

The Republic over two thousand years ago: "Do not, then, my friend, keep children to their studies by compulsion but by play" (cited in Kline, 1977, p. 199). Children naturally, spontaneously, and energetically love to play (Neill, 1960). Their love for this part of their life will act as the motivation to learn more about themselves in a physical and mathematical manner.

At the Fourth International Congress on Mathematical Education, at the University of California in Berkeley, California, 1980, grave concern was expressed as to the status of geometry in the schools of the world. The question was posed, "Is geometry as a school subject dead? What could revive it, or replace it? (Steen & Albers, 1981, p. viii). As an actualization of complementarity, the present research advocates that the teaching of elementary school mathematics through play and motor activities of Bhutanese children will enhance their geometric understanding of reality. This assertion was vividly expressed by Donald Albers in his article "Geometry Under Seige" which was presented at the Fourth International Congress on Mathematical Education, 1980. He proclaimed:

> We tell the child: "Look at yourself!" We point them to the most powerful and richest source of mathematical knowledge there ever was: themselves, their own body knowledge, their own intuitive geometry. Since the time they were babies, they were learning to get around in space. (Albers, 1981, p. 106)

The above quote again reaffirms the extreme value of the child's kinesthetic sense in his understanding of the world around him. As well, it draws a direct link between the aforementioned research on the hemispheric differences within the human brain and the concept of ethnomathematics. This connectedness (Sawada & Caley, 1985) is observed by focusing on the kinesthetic or proprioceptive sense--our sixth

sense (Balaskas, 1977; Blakeslee, 1980; Wittrock, 1977). Talbot (1977) equates the concepts of proprioception and kinesthesis, when he defines proprioception as:

> The sense of position and movement of the limbs, dependent upon sensory receptors' in skeletal muscles, joints, and/or tendons; also known as kinesthesis. (p. 202)

If we return to the game of archery, we can become more aware of the profoundness of the kinesthetic sense. As a Bhutanese boy prepares to shoot his arrow, he displays an amazing non-verbal and intuitive understanding of mathematics. By being able to feel the appropriate force in his fingers and shoulders as he draws the arrow back, he communicates a significant difference in how the two hemispheres of the brain approach and exhibit learning. Each time the arrow is shot the Bhutanese boy estimates the force, the trajectory path, considers the wind and the slope of the ground. Thus, his ability to shoot the arrow in an accurate fashion, exhibits a very sophisticated non-verbal understanding of physics which he more than likely could not explain verbally or through writing. What becomes so significant is if this young Bhutanese boy received a college degree in physics, he probably would not be able to write equations that would predict where the arrow will land as well as he now does intuitively.

To reiterate, the hemispheric specialization research portrays how the right hemisphere is superior to the left in a kinesthetic mode (Carmon, 1970; Corkin, 1965; Levin, 1973). We can also conclude that the left hemisphere is superior to the right in mathematical calculation (Blakeslee, 1980; Ornstein, 1972; Restak, 1984; Springer & Deutsch, 1981). Thus, what is needed is a holistic utilization of the above learning modalities, which will enhance the child's understanding of reality through the complementary use of the two modes of knowing.

Summary

In conclusion, this chapter has introduced the reader to the Himalayan Kingdom of Bhutan and the role of education in the development of this nation. Secondly, it has been shown that the concept of ethnomathematics has been described within Bhutan's new primary teacher education curriculum. Further, by recommending that Bhutanese children acquire the necessary mathematical skills of counting, ordering, sorting, measuring and weighing through their play and games, Bhutanese educators are suggesting that mathematics should be taught through an ethnomathematical medium. Consequently, these educators are implying that children can and should learn mathematics in a complementary manner.

CHAPTER FOUR

THE RATIONALE FOR AND PROCEDURES OF THE METHODOLOGY

The purpose of this chapter is to further portray how complementarity is the pervasive theme within this research and consequently within the methodology of the investigation. Initially, philosophical speculation will be presented regarding the concept of complementarity as the interwoven thread throughout this research; next, the research questions will be reiterated; subsequently, the appropriateness of the case study as the method of research will be presented; and lastly, the methodological procedures will be delineated.

The Interwoven Thread

The permeating theme within this research is that to educate children in a truly holistic and complementary manner, we must utilize the two modes of knowing and hence the two sides of our brain. Elementary school mathematics is traditionally conceived as a subject which involves logic, reason, analysis, sequence and order; thus, an area which taps predominantly the left hemisphere. Whereas, the play of children maybe described by such words as: non-verbal, intuitive, imaginative, spatial and spontaneous; words which are more characteristic of the right hemisphere. Therefore, it is proposed that children's mathematical school work and that children's play are complementary to each other.

Several aspects of the investigation exemplify how complementarity permeates the study. The investigation was conducted in the Eastern country of Bhutan by a researcher educated in the West. Bohr (1958a) indicates that in many ways these two cultures are complementary to each other. He states:

> The fact that human cultures developed under different conditions of living, exhibit such contrasts with respect to established traditions and social patterns allows one, in a certain sense, to call such cultures complementary. (p. 174)

Previously it has been stated that Bhutan is the only country in the world where Mahayana Buddhism is the state religion (Strydonck, Pommaret-Imaeda & Imaeda, 1984). As well, it has been disclosed that Buddhists see spiritual awareness and knowledge as the ultimate form of wisdom (Dorji, 1983a). Lastly, Niels Bohr has revealed that Buddha has considered and spoken about the fundamental epistemological problems that have also had to be confronted by the founders of atomic theory (Bohr, 1958b). Concomitantly, it has been stated that science and religion are two complementary manifestations of the mind reflected by rationality and intuition. The theoretical research presented suggests that the western scientist perceives the world through a highly developed rational mind, the Buddhist monk through a highly developed intuitive mind. These two approaches are entirely different but are complementary. Neither can be reduced to the other, nor can either be understood in the other, but both are absolutely necessary for a complete description of the world (Murdock, 1987).

Possibly the words of Werner Heisenberg (1963) best illustrate the potential inherent in two complementary cultures for an original contribution to knowledge. He states:

> It is probably true that in the history of human thinking the most fruitful developments frequently take place at those points where two different lines of thought meet. These lines may have their roots in quite different parts of human culture, in different times or different cultural environments or different religious traditions: hence if they actually meet, that is if they are at least so much related to each other that a real interaction can take place, then one may hope that new and interesting developments may follow. (p. 173)

The meeting of these different lines of thought has been realized through the interaction of a western educational researcher with the country of Bhutan and its unique culture, religion and people.

In a most compelling manner, the following result of the study of quantum mechanics, asserted by the physicist John Wheeler and his colleagues, suggests the methodological nature of the research. To reiterate, Wheeler et al. (1973) state:

> May the universe in some strange sense be "brought into being" by participation of those who participate?. . . The vital act is the incontrovertible new concept given by quantum mechanics. It strikes down the term "observer" of classical theory, the man who stands safely behind the thick glass wall and watches what goes on without taking part. It can't be done, quantum mechanics says. (p. 1273)

It is with this realization that a naturalistic paradigm--involving a case study with the researcher as participant observer--was chosen to investigate how pedagogy can be an actualization of complementarity; and how complementarity can become a theoretical structure for ethnomathematics.

In a complementary manner, the participant observer must rationally and intuitively respond to the social situation being studied. The concept of complementarity is not only the fundamental theme of this research project, it is the fundamental premise of doing participant observation as Powdermaker (1966) so candidly discloses:

> To understand a strange society the anthropologist has traditionally immersed himself in it learning as far as possible to think, see, feel and sometimes act as a member of its culture and at the same time as a trained anthropologist from

> another culture. This is the heart of the participant observation method--involvement and detachment. Its practice is both an art and a science. Involvement is necessary to understand the psychological realities of a culture, that is its meanings for the indigenous members. Detachment is necessary to construct the abstract reality: a network of social relations including the rules and how they function--not necessarily real to the people studied. (p. 9)

The Case Study

Guba (1981) indicates that educational research during the past decade has increasingly made use of the naturalistic inquiry paradigm. Guba and Lincoln (1982) further reveal that the distinguishing features of this paradigm are that it is carried out in a natural setting, that it utilizes the case study format, and that it relies strongly on qualitative research methods.

The case study method is a form of descriptive research which involves intensive investigation of one social unit (Asher, 1976). The unit may be a person, a family, a social group, or a social institution, such as a school. It can be whatever bounded system is deemed relevant for the inquiry (Stake, 1978). The objective is to comprehend the life cycle or a significant part of the life cycle of the unit (West, 1981). The case method probes deeply, and attempts to analyze the interaction between factors that create change or growth. Naturally, this requires detailed study for a considerable length of time, hence case studies are typically of a longitudinal nature.

Direct observation is an essential and major technique for gathering data within a case study. Borg (1981) asserts that the significant advantage of the observational process is that it allows the researcher to collect direct data about human behavior that can be gathered only indirectly by such measurement techniques as a pen-and-paper test. For example, we can probably learn much more about children's attitudes toward

a certain form of pedagogy by observing their interactions with one another while participating in the teaching medium, as compared to asking questions about the teaching strategy on a pen-and-paper test. Borg expands on the importance of direct observation:

> Direct observation is especially effective in situations where the researcher wishes to study in detail, specific aspects of human behavior. For instance the following questions are well suited for study by observation: "What specific teaching strategies are most effective to teach basic number facts to severely retarded children?" "How do preschool children respond to a television program that contains a high number of violent acts?" (p. 132)

For the purposes of this investigation, and thus as an actualization of complementarity, one might rephrase Borg's questions to read: (a) What specific teaching strategies are most effective to teach basic number facts to Bhutanese children? and (b) How do Bhutanese children respond to a form of pedagogy that involves their play and games?

Lastly, the case study method has been acclaimed to be a form of descriptive research contributing to theory building (Stake, 1978). Case studies often provide an opportunity for an investigation to develop insight into fundamental aspects of human behavior, and the intensive probing characteristic of this methodology may lead to the discovery of previously unsuspected relationships. However, Asher (1976) makes known that a case study must initially be encapsulated within a very thorough conception of behavior to give the data focus. "If done without reference to theory, the understandings developed will be superficial or of value for one or two cases alone" (p. 149). In conclusion, Stake (1978) discloses that case studies will continue to be useful for those who search for explanatory laws and advantageous as a basis for naturalistic generalization.

Methodological Procedures

This section of Chapter Four is intended to delineate the methodological procedures utilized by the researcher in the course of the investigation. It has been divided into five parts: (a) acquiring approval to conduct the research, (b) research setting, (c) subjects, (d) collection of data, and (d) analysis of data.

Spradley (1980), Spindler (1982) and Merriam (1988) state that in a descriptive investigation, such as a case study, the researcher should reveal an account of how permission was gained to conduct the research in a particular setting. Further, Wilson (1977) asserts that a reviewer of a descriptive research project needs to know such things as the researcher's background to assist the reviewer in judging the credibility of the investigation. For these reasons the methodological procedures begins with a sub-section focusing upon identification and gaining entry into the research setting.

Identification and Acquiring Entry

The investigator initially visited Bhutan in July of 1985 as an elementary education curriculum consultant in the area of Mathematics, Health and Physical Education. This curriculum development assignment was done under the auspices of the World University Service of Canada (WUSC). More specifically, this educational consultancy assignment dealt with the most effective manner in which the Environmental Studies Approach (EVS), now referred to as the New Approach to Primary Education (NAPE), could be implemented as a medium of instruction in the primary schools of Bhutan (Turner & Turner, 1985b; Turner, 1988b).

During this assignment, the investigator was able to ascertain the feasibility of conducting the research in Bhutan and whether this setting was in harmony with the theoretical orientation of the research (Turner, 1985).

The investigator initially discussed his dissertation research with the Chief Inspector of Schools, and subsequently, during a meeting with the former Director of Education, and the Chief Inspector of Schools, on August 14, 1985, permission was granted to conduct this research at the Teachers' Training Centre and Demonstration School (TTC/DS). This agreement was conditional upon approval from the Principal of TTC/DS, and the researcher being able to return to this institution as a lecturer under the administrative and financial support of the World University Service of Canada from June of 1986 to June of 1988 (Turner & Turner, 1985a). Further, a meeting was held on September 5, 1985 with the Principal of TTC/DS, to discuss the researcher's future assignment as a lecturer; as well, the investigator's research was discussed and permission was granted to conduct the investigation (Turner & Turner, 1985a).

Prior to returning to Bhutan in June of 1986, the researcher completed his candidacy examination, and his research proposal was approved by the Ethics Committee of the University of Alberta.

The Research Setting

Spradley (1980) lists five criteria for selecting a research setting for doing participant observation or a case study. They are: (a) simplicity, (b) accessibility, (c) unobtrusiveness, (d) permissibleness, and (e) frequently recurring activities. The Teachers' Training Centre and Demonstration School (TTC/DS), Paro, Bhutan was an ideal location for this investigation, not only because it met to a high degree the criteria delineated above by Spradley, but also because it has been regarded as an experimental

and exemplary educational institution since its inception. For example in 1977, the Demonstration School was officially created with the major purpose of providing practical teaching experience for the pre-service education of the teacher trainees.

Secondly, in March of 1986 the New Approach to Primary Education (NAPE) was implemented in twelve pilot schools along with the Demonstration School of TTC/DS. The Demonstration School was included as it was considered to be the only primary school in the country already utilizing a pedagogy based upon the immediate environment and culture of Bhutanese children, as well as experimenting with an activity oriented approach to learning.

Further, the exemplary role that TTC/DS has played and will continue to play in the educational system of Bhutan was recently reiterated by the present Director of Education. He states:

> In short, we have the earnest hope to develop the Teachers' Training Centre at Paro into a model institute based of which similar teacher training centres can be developed in other parts of the Kingdom. (Gyamtsho, 1988, p. iv)

Lastly, what becomes of paramount significance for this study is the realization that this investigation represents the first scholarly form of research that has been conducted at TTC/DS since its inception in 1974.

The Teachers' Training Centre and Demonstration School (TTC/DS): An Historical Sketch. This educational institution was initially founded in November of 1974 through financial and administrative assistance from the United Nations Children's Fund (UNICEF), the world agency for the well being of children. The goal of UNICEF cooperation then, as now, is for child survival and child development. UNICEF (1984) reports that infant morality in Bhutan is high, and literacy and life expectancy are low. While there is little evidence of overt malnutrition, the incidence of

intestinal infestations is common, and there are serious nutritional deficiencies resulting in the frequent occurrence of goitre which is a severe iodine deficiency disorder (Werner, 1977). Furthermore, nutritional anaemia is also a serious health problem. Since cooperation between UNICEF and the Royal Government of Bhutan began in 1974, infant mortality rate has dropped from about 300 per 1000 live births, to an estimated 147 per 1000 live births in 1983.

It is for these reasons that UNICEF believed that special care was needed for integration of pre-school care programs with a system of primary education, and consequently, in November of 1974, the Pre-Primary Teacher Training Centre was established in Paro. Initially, there were three teachers for the 200 lower kindergarten children registered. However, it was not until the fall of 1976 that fifteen students were entered into the pre-primary teacher training program. Furthermore, a report by Mathema (1976), under the auspices of UNICEF on teacher education in Bhutan, reveals that there was nothing even approaching a syllabus or curriculum of primary teacher education.

In 1977 the role of this educational institution was changed in accordance with the National Education policy. The major functions of this teacher education institute as outlined by UNICEF (1982) were defined as follows:

> (a) The Centre will be converted into a primary teacher training centre. Although it will continue to focus on the training of teachers for infant classes and the first few grades of the primary school cycle, it will not be exclusively concerned with pre-school education alone;
>
> (b) Under the supervision of the Centre, a primary school (up to Class V) will be established called the *Demonstration School* for practical teaching experience of the trainees; and

(c) The Centre was renamed the Teacher's Training Centre and Demonstration School. (p. 117)

By 1981 there were two batches of prospective primary teachers undergoing a two year training program. UNICEF (1982) reports that the teacher education course content consisted of the following:

(a) Professional courses: Methodology of teaching and content of infant courses,

(b) General education: English, science, arts and crafts,

(c) Background courses: Child development, hygiene, nutrition and administration,

(d) Practical training: practice in teaching and child care. (p. 116)

In the initial year, the teacher education program consisted of about 60% of the time doing practical, pedagogical work while the remaining 40% focused upon theory courses. In the second year, the trainees spent 80% of the term on their practicum, and the remainder on course work.

In July of 1986, the two primary teacher education institutes of Bhutan, namely, the National Institute of Education (NIE), and the Teachers' Training Centre and Demonstration School (TTC/DS), planned and implemented the same curriculum. This change marked the first time in the history of TTC/DS that it would be responsible for the education of prospective teachers for all levels of the primary school, they being one year of kindergarten through six years of further schooling.

Another significant curriculum change occurred within Bhutan's educational system in 1986 when the New Approach to Primary Education (NAPE) was implemented in 12 pilot schools along with the Demonstration School of TTC/DS. The NAPE curriculum has as its major focus the concept of subjects being based on the

immediate environment and culture of Bhutanese children, and emphasizes an activity oriented approach to learning. This form of pedagogy complements the predominant medium of learning by rote which has been passed to the Bhutanese primary education system by the Buddhist monasteries and the school system of India (Bailey, 1987; Pommaret-Imaeda, 1987). (Recall that close to 50% of Bhutan's primary education staff are expatriates from the neighboring country of India.) However, TTC/DS since its inception has always emphasized an activity oriented approach for the education of pre-school children under the title of the playway method (UNICEF, 1984).

Finally, the above historical sketch of the Teachers' Training Centre and Demonstration School has attempted to create an image of this educational institution and the role it has played and will continue to play in the education of children and teachers of Bhutan.

The Subjects

As has been previously stated, the New Approach to Primary Education (NAPE) and its curriculum were implemented at the Demonstration School of TTC/DS in March of 1986. This new pedagogy and curriculum were piloted up to and including class three, while classes four to six retained their subject teaching system as well as their previous curriculum. Consequently, the researcher discussed this investigation with the class teachers of the pre-primary (PP) to class three grades and two teachers firmly expressed interest in participating in the study.

Thus, the subjects of this case study and their pseudonyms were Mr. U. T., a primary teacher with five years teaching experience at this grade level and the thirty-seven children of his pre-primary (kindergarten) class in 1987. The second group of subjects were Mr. T. N., a primary teacher in his second year of teaching and his

thirty-seven class two children. It is important to note that Mr. T. N.'s children were taught by him during the 1986 school year as class one students. Each of the above teachers was considered to be one of the top two graduates of his respective convocating class from TTC/DS and was asked to remain at the Demonstration School as a teacher upon graduation.

Thirdly, the twenty-four second year and twenty-nine first year primary teacher trainees, referred to respectively as "Batches XI and XII," acted as facilitators in the teaching of elementary school mathematics through the play and movement activities of the above children. The final subject in this research project was the investigator as a participant observer.

Collection of Data

The Primary Research Instrument. In a case study, the investigator as participant observer becomes the main research instrument. Wilson (1977) clarifies this role by stating:

> The qualitative research enterprise depends on the ability of the researcher to make himself a sensitive research instrument by transcending his own perspective and becoming acquainted with the perspectives of those he is studying. (p. 261)

Eisner (1981) supports this assertion by stating: "In artistic approaches to research, the major instrument is the investigator himself" (p. 8). As well, Herriott and Firestone (1983) proclaim that in qualitative research the researcher is frequently the *crucial instrument* of the investigation.

Further to this, several researchers speak about the vital importance of the participant observer being able to respond to the persons in his study in an empathic manner. Wilson (1977) affirms that the participant observer must create an empathic

understanding with the participants by sharing their daily life and striving to understand their innermost thoughts and feelings. Eisner (1981) writes of the importance of the experiences that the participants are having and the meaning they attribute to these experiences. In order to fully understand these experiences Eisner proclaims that the participant observer must indwell, empathize, project himself into the life of the people he is studying.

In a complementary manner, the participant observer as the primary research instrument must indwell and empathize with his subjects, and then almost simultaneously and paradoxically draw back, attempting to see from an outsider's view. These two descriptions by the participant observer, though mutually exclusive, are nonetheless both necessary for a complete description of the phenomena being studied. It was through this process of recursion, while observing and being with the participants over a period of one school year, that the investigator was able to collect data relevant to the focus of this study.

Smith (1978) speaks of the above relationship between the participant observer and the participants he is studying as being similar to a "Rogerian counseling relationship." Hence, this researcher concludes that his credibility as a research instrument is strengthened by the fact that he has had three years training at the Masters level in Rogerian counseling and has worked as a guidance counselor in an elementary school for a two year period. It should be noted that training in Rogerian counseling places significant emphasis on learning how to respond in an empathic manner. Proponents of the work of Carl Rogers, namely Carkhuff and Truax (1977), have shown that this interpersonal skill can be taught and learned. The purpose of this lengthy preamble about the participant observer and his role as an empathic listener is in

response to Wilson (1977), who promulgates that a reviewer of a descriptive research project needs to know such things as the researcher's training and background to assist him in judging the credibility of the research.

The credibility and trustworthiness of this research was also enhanced by the fact that the researcher, on four separate occasions during the period of the investigation, received guidance and consultation in the collection and interpretation of the data from F. Pommaret-Imaeda, an anthropologist (University of Paris, Pantheon-Sorbonne, 1985) who conducted her dissertation research in Bhutan. F. Pommaret-Imaeda is now working as the history consultant for the Department of Education in Bhutan and is currently writing Bhutanese history texts for the elementary and secondary schools (Pommaret-Imaeda, 1988). Moreover, "triangulation" (Merriam, 1988) was additionally achieved during this longitudinal study through daily discussions with Mr. T. N. and Mr. U. T. concerning the researcher's collection and interpretation of the data. The audio-visual data collected also served to create a triangular check on the researcher's interpretation of the data.

Sources of Data. With regard to the kinds of data that were collected, Wilson (1977) states that descriptive research is multimodal and the following represents relevant genres of information:

1. Form and content of verbal interaction between participants;
2. Form and content of verbal interaction with the researcher;
3. Nonverbal behavior;
4. Patterns of action and nonaction;
5. Traces, archival records, artifacts, documents. (p. 255)

The major means by which these kinds of data were collected was by field notes. Spradley (1980) pronounces that the primary segment of any descriptive or qualitative record consists of written field notes.

In the recording of these field notes the investigator followed the format outlined by Spradley (1980). This format includes: (a) the condensed account, (b) the expanded account, and (c) the fieldwork journal. The condensed account represents all the notes that were taken during a field observation like single words, phrases, complete and open sentences; that is, any written symbols that aided the researcher when he created his expanded account after completing an observation or interview. This genre of fieldnotes represented an expansion of the condensed notes and was done as soon as possible after the field session was completed.

The third kind of fieldnotes which Spradley (1980) recommends collecting is in the form of a field work journal.

> Like a diary, this journal will contain a record of experiences, ideas, fears, mistakes, confusions, breakthroughs, and problems that arise during fieldwork. A journal represents the personal side of fieldwork; it includes reactions to informants and the feelings you sense from others. (p. 71)

In total, the equivalent of 247 typewritten field note pages were collected during this case study.

In addition to fieldnotes, the researcher made use of the following audio-visual equipment to document the data: (a) a tape recorder, (b) a slide film camera, and (c) a video camera. The use of this equipment in descriptive research is supported by several researchers as Smith (1978) reveals:

> Some educational anthropologists (Cazden, John and Hymes, 1972; Cicourel et al., 1974 and Erickson, 1975) pursuing more specific substantive problems in the "new ethnography" rather than the broader, more holistic study of a group or a community, have moved to audio and video tapes of classroom events and

> the beginnings of qualitative analyses of these. From these records, they reconstruct the implicit meanings in speech and nonverbal behavior. (p. 344)

In addition, Fetterman (1982) when discussing the documentation of data in a major qualitative project stated that: "A tape recorder and camera were invaluable in collecting and documenting the data" (p. 20). The importance of the use of video tapes in gaining a deeper understanding of the development of children is also strongly recommended by Sutton-Smith (1980), who has written extensively on the value of play in the growth and development of children. In sum, twenty-five hours of audio-visual data, 251-35 mm slide film frames, and six hours of audio data complement the field notes.

This data was gathered over a period of nine months beginning on March 9, 1987 through December 17, 1987. This time interval represented the full school year for the Demonstration School. Smith (1978) speaks of the significance of such a time frame:

> In regard to our data collection, we have tried to be around for a period of time that reflects commonsense boundaries--a semester, a year, the life of the project, and so forth. . . .Schools, in part, have an annual or semiannual opening or beginning; an establishment of order, structure and routines; a long steady state period; and a closing or termination of the year. (p. 343)

A Typical Week. As previously stated, Spradley (1980) points out that the investigation of any social unit, as in a case study, involves three primary elements, namely, a setting, subjects and activities.

During a typical week of this year long study at the Teachers' Training Centre and Demonstration School (TTC/DS), two class meetings were held with each group of children. In the initial meeting, one group of trainees would have helped the children to more fully understand a mathematical concept or problem by using a medium that involved play, games or was high in motor activity. This lesson would have been

designed by the researcher and the particular classroom teacher during a meeting prior to the beginning of the weekly classes and would have been introduced to the teacher trainees by the investigator who was also their mathematics lecturer. The word introduced is used as the teacher trainees played a significant role in the actual planning and implementation of these lessons with the children. Further, the content for the lessons was based upon the new primary school mathematics curriculum which was originally written in August of 1985, and since slightly revised by the primary school mathematics curriculum consultant of that time (Turner & Turner, 1985b; Turner, 1988b).

The second lesson that the children experienced each week was intended to be a follow-up to the initial lesson and was to enable the children to repeat, practice and apply what they had learned. In their weekly meetings the classroom teacher and researcher would have discussed the content for the follow-up lesson; however, the actual procedure was the choice of the classroom teacher based upon what he believed would be an extension of and expansion upon the previous lesson. Normally, the classroom teacher was the primary facilitator in the second lesson and the researcher acted as a participant observer.

The involvement of the two classes of teacher trainees within these lessons was dependent upon their curriculum as the XII batch (first year trainees) did not take part in the study until joining the institute in July of 1987. Further the XI batch (second year trainees) were involved in an eight week practicum during the 1987 calendar year and obviously did not partake in the study during that time. When both groups of trainees were present, one batch worked with one group of children and the other with the second primary class.

Analysis of Data

Spradley (1980) reveals that the analysis of data in a qualitative research project is an ongoing process involving questions and discoveries. He asserts that the researcher analyzes the field data compiled from participant observation to ascertain questions that give direction to the research. Spradley continues by stating:

> You need to analyze your fieldnotes after each period of fieldwork in order to know what to look for during the next period of participant observation. (pp. 33-34)

This researcher sees the analysis of participant observation data as being a very logical process. It is the search for patterns, for relationships, for emerging order (Sawada, 1986). Under the heading *Thinking During Data Collection,* Smith (1978) responds to the question "What does it all mean?" by stating:

> This is a search for overall patterns, for broad themes which seem to break the phenomenon into large chunks or domains. This is an active search for order. (p. 333)

The analysis of data involves the logical and ethnomathematical processes of counting, ordering, and sorting; however, simultaneously, as the t'ai chi figure symbolizes, intuition, imagination and spontaneity must be exhibited by the investigator, the participant observer. Merriam (1988), in the book, *Case Study Research in Education,* concurs by stating:

> The chapters in this part of the book are presented with the awareness that detailed instructions in analyzing and reporting qualitative case study data, though helpful, are merely guidelines in need of interpretation and application by the single most important component in qualitative research: the investigator. (p. 122)

Further, Merriam (1988) states that the analysis of a case study has three hierarchical levels: (a) the descriptive account, (b) the creation of themes, and (c) the development of theory. Consequently, Chapter Five: The Case Record, focuses upon

a "rich, thick" description of the data collected, and has as its major objective the transporting of the reader to the research setting.

Goetz and Le Compte (1984) point out that many qualitative investigations stop here and fail to transcend the merely descriptive. They state:

> By leaving readers to draw their own conclusions, researchers risk misinterpretation. Their results also may be trivialized by readers who are unable to make connections implied, but not made explicit, by the researcher. (p. 196)

Thus, Chapter Six: Analysis and Discussion centres upon the creation of themes and the development of theory from the data.

Developing themes involves interpreting the data by searching for recurring regularities (Merriam, 1988). A theme may be thought of as a behavioral pattern that frequently recurs in a case study so as to characterize it. In addition, this research presents the analytical concept of "propositional theme" to examine the data. The word propositional is used in its mathematical sense and denotes a formal statement of truth to be demonstrated. In the context of this research and by definition, a propositional theme is a recurring behavioral pattern, which denotes a fundamental truth that will be shown through demonstration to be an actualization of complementarity. This leads us into the third level of analysis, that being the development of and building upon theory by explaining the phenomena and indicating how they are related. Merriam (1988) concurs by stating:

> When categories [themes] and their properties are reduced and refined and then linked together by tentative hypotheses, the analysis is moving toward the development of a theory to explain the data's meaning. (p. 146)

CHAPTER FIVE

THE CASE RECORD

In the book *Case Study Research in Education*, Merriam (1988) points out that the first level of analysis in a case study is a rich description of the data. The author indicates that this is commonly referred to as the "case record" or the "case study data base" (p. 126). Merriam states, as does Spradley (1980) and Goetz and Le Compte (1984), that the purpose of the case record is to transport the reader to the research setting so that the reader may be given the opportunity to perceive the situation as the case researcher has done. Consequently, the objective of this chapter is to provide the reader with a portraiture of the school year, full of imagery, as experienced by the researcher. By presenting the case record in a non-evaluative, comprehensive, and descriptive manner, the researcher believes that a context can be provided for the theoretical analysis contained in the next chapter, which focuses upon an analysis and discussion of the data.

In addition, Wilson (1977), Spradley (1980), and Merriam (1988), reveal that a case record is usually presented in chronological or topical format. Since this research focused on an entire school year, the case record will be presented in a chronological fashion and will be divided into six phases, which reflect the culture of the 1987 academic year at the Teachers' Training Centre and Demonstration School, (TTC/DS), Paro, Bhutan.

Phase I: 9 March to 18 April 1987

Phase I introduces the reader to the Teachers' Training Centre and Demonstration School, (TTC/DS) as well as to the teachers and the children of this investigation, which include Mr. T. N. and his 37 class "II B" children along with Mr. U. T. and his 37 pre-primary (PP A) class.

TTC/DS, Mr. T. N.'s and Mr. U. T.'s Classes

The Teachers' Training Centre and Demonstration School (TTC/DS) is a small institution situated along the banks of the Paro River. It is the educational home for over fifty teacher trainees and approximately five hundred primary school children. The buildings, constructed from concrete and mud, show the wear and tear of being in operation for fifteen years.

The grounds surrounding TTC/DS are dusty and bare with small patches of grass struggling to survive under the ever-treading feet of the children of the Demonstration School. A few flowers outline the main walk towards the Principal's office, the result of the Saturday morning Social Work program, in an effort for rural beautification. Beside the main building lies the cook house, a simple log cabin style structure which houses two earthen fireplaces and gigantic black pots which sit on the open fires. Two cooks are in charge of preparing lunch for the children in the Demonstration School using supplies provided by the World Food Program.

The classrooms are scattered close by the main office building and are small rooms, dimly lit with windows covered by shutters but no glass. Most classes have the luxury of decrepit desks and benches however, in some, especially the Pre-Primary classes, the children are forced to sit on the dusty, wooden floor.

Each classroom boasts a few hand made visual aids proudly displayed by the teacher, who would often refer to the pictures or charts during the course of the daily lessons. A common feature accompanying every Bhutanese class is a room full of bright, shining eyes, eagerly awaiting to explore an unknown world through the guidance of their teachers.

The TTC/DS school year opened for that year on 9 March 1987. As is customary in all Bhutanese schools, the day began with the morning assembly. A sea of young school children, dressed in the traditional school uniform of either a "kera" for the girls or a "kho" for the boys, formed neat, straight rows according to class level. On the command of the school captain, they all stood at attention while singing the National Anthem followed immediately by the chanting of a Buddhist prayer.

After a few opening announcements by the Principal, the teachers and children were then dismissed to organize and clean their classrooms as well as complete the necessary registration for the new school year. Actual classes did not commence until 11 March.

Mr. U. T.'s PP A Class and Matching. The researcher met twice that first week with Mr. U. T. and Mr. T. N. During the meetings with Mr. T. N. the discussion centered around the first topic in the class two mathematics syllabus, place value, which Mr. T. N. would introduce to his students. Mr. U. T. indicated that he was planning to begin with the mathematical concept of matching and it was agreed that the researcher would observe his class the following week.

On Monday, 16 March, the researcher observed Mr. U. T. and his PP A class for the first time. Upon entering the dingy classroom, the researcher delighted to see

thirty-seven small, dark eyed children sitting on the bare floor. The children, too, appeared equally delighted to see this foreigner entering their small world.

Also present were three trainees who were assigned to Mr. U. T.'s class for observational purposes. This mathematics lesson focused upon having the children raise their right and left legs, in a marching fashion, while stepping in time with Mr. U. T. as he commanded in English, "Left, right--Left, right." Following this marching exercise, the children drew pictures of their hands on the wooden floor with bits of chalk and then matched a hand with their drawing.

Mr. T. N.'s Class II B, the "AEIOU" Song and Place Value. On that same day the researcher observed Mr. T. N.'s class for the first time. Earlier the children had been singing the "AEIOU" song and when the researcher entered the classroom all 37 dark heads were bowed, busily trying to write five words with each vowel sound. A few children peeked up shyly and flashed quick smiles as they noticed the researcher enter. With a brief glance around, the researcher observed neat rows of benches and desks, a dusty wooden floor, and several glassless windows. Mr. T. N.'s room was a newly constructed auxiliary classroom, resembling a log cabin from the outside and was more luminous inside because of the additional windows. Three trainees were also observing this class of which 27 students were with Mr. T. N. in class one and the remaining 10 were repeating class two.

The children eagerly sang the AEIOU song again and subsequently began to generate words with the "short a" vowel sound while Mr. T. N. recorded them on the board. As the children diligently copied the words from the board they would spell and pronounce each one. They followed this same procedure using the "short e" vowel

sound and a constant murmur was always present as the children pronounced the letters of each word and recorded them from the board.

The following day the researcher again visited Mr. T. N.'s class in order to observe a Mathematics lesson dealing with place value. As is the custom, when the researcher entered the children all rose and greeted him by saying, "Good Morning, Sir." The researcher noticed the children all had sticks with them, which Mr. T. N. asked to be put in their desks.

Mr. T. N. began by focusing on single digit numbers which he wrote on the small, easel-style blackboard and asked, for example, "How many ones in six?" He then progressed, by demonstration with the sticks, to two digit numerals. "In one tens there are how many ones?" Mr. T. N. enthusiastically continued by writing 27 on the blackboard and then demonstrated with the sticks by grouping them in bundles and stating that, "One tens and one tens makes two tens. How many ones, how many tens are there? Two tens makes how many ones? Look here, look here, don't play with the sticks now!" asserted Mr. T. N. Utilizing expanded notation Mr. T. N. wrote 27 = 10 + 10 + 7 on the board. He continued with this procedure using other two digit numerals. Then he asked the class whether place value is in the direction of "Up and down or right and left." The children promptly replied, "right and left."

Mr. T. N. next introduced the two digit numerals 94 and 49 for comparison purposes and subsequently wrote zero on the board and asked, "What does it mean?" Six students were asked to stand and the question was posed to the class as to the number of students standing. They were instructed to sit down and the class was asked, "Now how many students are standing? If I write 20, look here, two tens is equal to how much? Count two tens with your sticks."

Mr. T. N. continued by comparing "09" to "90" and then proceeded onward to three digit numerals by asking what each digit represented in such a numeral. Mr. T. N. and the children, now through choral recitation, began to count from one to one hundred as Mr. T. N. displayed one stick at a time. After accumulating one hundred sticks on his desk Mr. T. N. said, "In 100, how many ones are there?" and the children replied, "100 ones." "Now lets group in tens," encouraged Mr. T. N., "Now look here everybody, lets make groups of tens. Look here, everybody, let's see how many tens we can make." The children noisily counted aloud with Mr. T. N. and one student stood and held the first set of ten. Another student was called forward and together these students eventually held the groups of ten sticks which were being counted aloud by Mr. T. N. and the children. "So how many tens?" asked Mr. T. N., the children replied, "six tens." Eventually, Mr. T. N. stated, "Hundred means ten groups of tens." Mr. T. N. stopped and stated, "Now Dzongkha, put sticks inside," and the children began to prepare for a class in their official language.

In addition, on Tuesday, 17 March, the researcher met with Mr.U. T. and he indicated that of the 37 children in his class, 35 were in his pre-primary (PP) class of last year. Also, Mr. U. T. stated that it is very important for a PP teacher to be able to act out and demonstrate directions especially when a second language is being used as the medium of instruction.

On Thursday, 19 March, the researcher observed Mr. T. N. and his class II B children during a mathematics lesson focusing upon place value. "How do you read this number?" questioned Mr. T. N., as he wrote 247 on the blackboard. "What does it mean? It means two hundreds, four tens and seven ones. Read that number. Which side will be ones? Which one is the right side? Read that number 434. What it

means?" prompted Mr. T. N. The children loudly exclaimed, "Four hundreds, three tens and four ones." Mr. T. N. then noted a parallel between spelling a word and reading a number from left to right.

Mr. T. N. continued by drawing a place value chart on the blackboard which made use of the hundreds, tens and ones columns. "Look here, look here," exclaimed Mr. T. N. "If I say 9, where do I write the 9?" Mr. T. N. put the 9 in the tens column and the children said "No, Sir." "Here," Mr. T. N. then put it in the hundreds column. Again the children repeated, "No, Sir." Mr. T. N. stated, "Twenty-two means--two tens and two ones. Look here, everybody," exclaimed Mr. T. N. as he hit the duster twice against the blackboard to get the children's attention. "If I say, 132, what it means? Think of one hundred, three tens and two means, what? Two ones. How do you read this number, 456? Look here, look here, look here everybody." Mr. T. N. erased the six from the number 456 and then asked the children, "What it becomes now? What it means?" The children clearly stated, "Four tens and five ones." "Forty-five means four tens and five ones, isn't it," asserted Mr. T. N.

Mr. T. N. continued the lesson by making use of a place value chart utilizing the hundreds, tens and ones columns and proceeded to analyze three digit numerals. At that point in the lesson Mr. T. N. asked any children to stand up who did not understand. One third of the class or twelve children shyly stood up. "Twenty-three, where shall I write this two?" asked Mr. T. N., referring to where should he write the two in the place value chart. "Read it," exclaimed Mr. T. N. and the children stated, "Two tens and three ones."

The lesson concluded by Mr. T. N. getting the children to take out their exercise books for the purpose of placing five different numerals on a place value chart. Mr. T.

N. gave the questions and stated, "Now, you just make columns." The children were busy saying the numerals to themselves and diligently writing them in the place value charts they had drawn. They soon clustered around Mr. T. N.'s desk individually and in small groups to have their work corrected.

Mr. U. T.'s Class and Mass Play. That same day, 19 March, the researcher observed Mr. U. T.'s class once more. When the researcher entered the children were sitting cross-legged on the floor in three rows while Mr. U. T. was collecting materials for the class. Three trainees were also present for observational purposes. Mr. U. T. began the class by stating, "Everybody fold your hands." He held up a soft drink bottle and asked, "What is it?--it's a bottle." The children repeated "It's a bottle," several times. Mr. U. T. followed the same procedure using several objects, such as, a lock, tin can, brush, piece of paper, horn, etc. Following this Mr. U. T. wrote on the blackboard the words "heavy and light." Subsequently, he called one student at a time to the front of the class in order to hold two of the objects simultaneously and to state which object is heavy and which one is light. Following this Mr. U. T. said, "Stand up" and he spoke to the children in Dzongkha. The children joined hands, made a big circle and sat down. Mr. U. T. brought out a ball and tire and stated, "The ball is light and the tire is heavy." The children passed the ball to the left and the tire to the right; Mr. U. T. soon introduced another tire to be passed and another ball which the children passed behind their backs.

Mr. U. T. had to leave the classroom and when he did several mischievous boys began to push and punch each other. Upon returning, Mr. U. T. told one boy, as a form of punishment, to "catch your ears and stand on your left leg" which the boy did for approximately two minutes.

Mr. U. T. then told all the children to "stand up" and continued by speaking in Dzongkha. The children began to play with the many things and objects in the classroom such as wooden blocks, tires, tin cans, bottle caps, and materials from foreign made geometry sets. The boys, who numbered twenty-two, were actively involved in running, jumping and pushing the tires as well as dancing like masked dancers to the beat of quick, quick, slow as one boy played an old wooden box as though it were a drum. The girls, who numbered fifteen, stayed sitting in small groups quietly building with the blocks and sorting objects like the bottle caps. Eventually, twenty-two of the thirty-seven children were busily building things with the blocks while the others remained jumping and dancing about.

Mr. U. T. and the researcher met later and discussed the latter part of his lesson which he defined as "mass play." Mr. U. T. said that he did not believe the children were enjoying the large group structured lesson and decided to let them play. Mr. U. T. mentioned that the one boy who was beating the wooden box as a drum with the rhythm of quick, quick, slow was imitating the drummer of the Paro Tsechu (religious festival), which would take place from 9 to 14 April 1987 in the Paro District.

During the three week period from 22 March to 8 April 1987, the researcher was involved with the practicum supervision of trainees from the XI batch who had been placed at Drukgyel and Dotey primary schools in the Paro Valley. Consequently, the introduction to Mr. T. N.'s and Mr. U. T.'s classes ends at this time.

As stated in the aforementioned, the Paro Tsechu, an annual religious festival and holiday period, occurred from 9 to 14 April 1987 in this district of Bhutan. Later that week, the researcher met with Mr. U. T. and Mr. T. N. on 18 April and it was agreed that the trainees (XI batch) would begin to work with their classes the following

week. Mr. U. T. indicated that his children were still focusing upon sorting and matching while Mr. T. N.'s children were involved with the addition of money.

Phase II: 20 April to 1 June 1987

This six week period of data collection is characterized by the fact that the trainees (XI batch) taught mathematics, through a medium high in physical activity, one period per week to each of Mr. T. N.'s and Mr. U. T.'s classes. In addition, Mr. U. T. and Mr. T. N. instructed a follow-up lesson immediately after each of the sessions taught by the trainees.

During the five lessons which involved Mr. U. T.'s PP A class and the trainees, the topics of matching and making numerals were covered. All lessons by the trainees involved activities high in movement as well as utilizing the kinesthetic and the tactile modalities. The sessions took place out of doors with one exception due to inclement weather. The trainees made use of the existing environment, using stones, sticks and sand as tools for instruction. However, it was soon discovered by the trainees that the most important teaching aid was always at their disposal; that being, the children themselves.

While focusing on the topic of matching, the trainees involved the children in a series of activities promoting body mirroring, where the trainees would do a particular action and the small PP A children would eagerly attempt to imitate the action they saw. On one occasion, the researcher observed all 37 PP A children and 24 trainees out upon the dusty football ground and basketball court. In the brilliant sunshine, giggling with glee and moving with the unlimited energy only children seem to experience, the PP A

class learned the mathematical concept of matching through a style and setting found outside the boundaries of the traditional classroom.

The follow-up lessons involving Mr. U. T. also used activities involving gross and fine motor co-ordination. Out of the four follow-up lessons observed, Mr. U. T. took his children outside once and remained inside for the other sessions.

During this phase, the trainees and Mr. T. N.'s class II B were exposed to one main topic in mathematics which was place value. However, during the course of their five instructional lessons sub topics such as, addition using decimals, money and measurement were also focused upon. Again, the trainees took advantage of the immediate aids in the area. The class II B children could be seen constructing play money from stones, leaves and sticks, as well as composing songs to help them over the hurdle of remembering and understanding decimals.

Mr. T. N.'s lessons were active both inside and outside of his classroom. He complemented the trainees' lessons by continuing to use a game which the student teachers had taught his class. He also had his children busily measuring just about everything possible in the classroom and recording their findings in their exercise books. Mr. T. N. reinforced the children's creative and natural desire to sing, by using the songs they had developed with the trainees, within his mathematics class.

At this time the researcher would like to present a detailed description of the following four lessons. (a) Mr. U. T.'s class and the Trainees, (b) Mr. U. T. and his class (follow-up), (c) Mr. T. N.'s class and the Trainees, and (d) Mr. T. N. and his class (follow-up). These particular lessons were chosen as they were judged to be typical of the lessons which the researcher observed during Phase II.

Mr. U. T.'s Class, the Trainees and the Construction of Numerals. On Monday, 4 May during the first period the trainees and the researcher talked about the meaning of kinesthesis and its importance in how a child learns and, then, subsequently focused upon ways in which Mr. U. T.'s children could make the digits from zero to nine using their fingers and body. Working in partners, the trainees practiced means by which they could accomplish this task prior to proceeding to their designated area, which was either the library, the veranda, Mr. U. T.'s classroom or their own classroom. In turn Mr. U. T. divided his children into four groups who were escorted to a specific area with the help of the trainees.

In one group, the trainees by twisting and turning their hands and arms made different numeral shapes and requested their children to trace the shape in the air while naming it. In Mr. U. T.'s classroom, two trainees also made numeral shapes with their hands and arms while the children named the numeral and wrote it in the dust on the floor. Following this, the children delighted in making their numeral shapes, while the student teachers attempted to guess what the small forms represented. With waving arms and pointing fingers, the children of another group drew their shapes in the air, under the watching eye of a student trainee.

In the library two student teachers, after having the children see the numerals, got their students to trace the numerals in the air and make them with their hands. Two other trainees had their students sit on the floor folding their short bare legs into a cross-legged pose to construct the number 4. The energetic session concluded with all the trainees and children singing, "I Can Count from 1 to 10."

Mr. U. T.'s Follow-Up Lesson and the Construction of Numerals. The following day, Tuesday, 5 May the researcher visited Mr. U. T.'s class in order to

observe his follow-up lesson. Mr. U. T. was speaking with someone when the researcher entered, so the researcher and the children sang, "I Can Count from 1 to 10."

Mr. U. T. displayed a brilliant, red arrow which had been made from cardboard and got the children to point to the left, up, right and down matching the direction of the arrow. Secondly, Mr. U. T. got the children to draw in the air, or on the floor the numerals one and two. As well as tracing the numeral three in the air, several children attempted to construct it with their fingers while others made the numeral two by twisting and turning their arms. Mr. U. T. assisted the children by giving instructions in Dzongkha. Next the numeral four was created using their left index finger and thumb to create an "L" shape, while the index finger of the right hand completed the construction for four.

The children continued to make the remaining digits using their small, nimble fingers while Mr. U. T. assisted them through instructions in Dzongkha. Upon reaching the digit nine, the children stood and by making a circle with their left arm that touched their head, they constructed that numeral. Ten was made by using the index finger of the left hand for one, while the index finger and thumb of the right hand represented zero.

Following this the children sang "I Can Count from 1 to 10" three times; subsequently, the boys stood and sang for the girls and then the girls sang this same song for the boys. "Here We Go Loop de Loop," followed as did "Here We Go Round the Mulberry Bush." The class ended by once again singing the favorite tune, "I Can Count from 1 to 10."

Mr. T. N.'s Class, the Trainees and the Binary Adding Game. On Wednesday, 6 May, the researcher met with the trainees and discussed the meaning of kinesthesis and its importance in children's growth and development. The activity that day for teaching place value was a variation of the binary adding game that the trainees had learned in February at the NAPE training session. In this motor activity three children stand side by side and the person in the middle joins hands with the persons beside him. If these persons raise all hands, one facing the group would read the numeral as 1,111. If an arm is not raised then that denotes zero; for example, if the three persons stand with all arms down then the numeral zero has been constructed.

Half the trainees worked with Mr. T. N.'s children teaching this activity, and the other half who did not compose mathematical songs last week would do so during this period. Prior to meeting with Mr. T. N.'s class, the trainees practiced the place value activity in groups of four with one trainee acting as the numeral caller. The other group, which was subdivided into two singing groups, began to compose their base ten songs. Following this all of the participants congregated on the assembly ground and divided into a ratio of one trainee to three children for the purposes of teaching the base ten motor activity.

In most groups the trainees initially acted as the caller but by the end of the session some trainees had one of the children calling the numerals while they acted as a place value holder. At 10:20 a.m. the singing group of trainees arrived and proceeded to divide into four instructional groups with the children and other trainees. The trainees had created songs in which the children would make use of the motor patterns that had just been learned. The lyrics of the first song entitled, "Song of Base Ten," were:

Person on the left side
raise your left hand,
Which will give us figure 1.
Oh! When we multiply, that by 10,
down your left hand
raise your right.
That will make the figure ten times more,
If we multiply that by ten,
we will be in the 100's place

The lyrics of the second song entitled, "These are the Games of Base Ten" were:

These are the games of base ten
We'd like to play it
Those are 1s, 10s, 100s, 1000s!
Those are 1s, 10s, 100s, 1000s!
We count it from 1 to 10
Because it is the game of base ten.

While singing both songs whole heartedly, the children were instructed by the trainees to raise their arms at the appropriate time. The class ended at this time as the researcher received a message from the Principal indicating that she wished to speak with the trainees.

Mr. T. N.'s Follow-Up Lesson and the Binary Adding Game. Prior to assembly on Thursday, 7 May, Mr. T. N. and the researcher met to discuss his follow-up lesson. Mr. T. N. thought it best to go outside to the clay basketball court and have the children work in groups of four so that one student could act as a caller.

When the researcher arrived at Mr. T. N.'s classroom, the children were patiently waiting for the student who was in charge of the key. Upon entering the classroom the children sang the "Good Morning" song. Mr. T. N. arrived and announced , "Do you have your groups, as we are going outside?" The children spontaneously showed their enthusiasm for this idea as they stood and cheered. All

participants proceeded to the basketball court and while the children divided up into their groups, Mr. T. N. instructed that the students should take turns at being the caller.

Instinctively, the children began to record the numerals. One group made use of a grid, four by four, and placed a zero in the grid wherever an arm was not raised. Another group of children, using broken sticks and pointed stones, began inscribing on the clay surface, the numerals without the use of a grid, and further groups began doing the same as they observed each other. A common mistake made by the children was the recording of 1001 for one hundred and one, or 10001 for one thousand and one.

Many children began to collect pebbles from the nearby river bed and made numeral outlines with the small stones. When the researcher departed after one and one-half hours, almost all children were still squatting beside their digit patterns, diligently involved in drawing or forming their creations with the use of pebbles and tiny stones. Later in the day, Mr. T. N. remarked that he believed the children had learned a lot from observing each other.

Phase III: 3 June to 3 July 1987

Phase III is unique in that during this time the researcher observed or was actively involved in the lessons taught by Mr. U. T. and Mr. T. N. The trainees (XI batch) did not participate in this phase as they were writing their final examinations and then were granted holidays until June 30, 1987.

The researcher observed four lessons by both Mr. U. T. and Mr. T. N. The topic covered in the PP A class was addition of single digit numbers; whereas the

children in Class II B continued with measurement and later were introduced to multiplication.

Both class teachers in this research tried to incorporate games, indigenous as well as others, in all of the mathematical topics covered. Some of these games were very successful while others involved alterations to meet the level of the children.

The indigenous game of "Apeygodo" (phonetic English spelling of Dzongkha word) was taught to Mr. U. T.'s PP A class. This game used to be played by Mr. U. T., as a child while watching over his father's cattle, in the open fields of eastern Bhutan. The game involved stones and circles drawn on the wooden floor of the classroom.

The small PP A students watched quietly and with curious interest as Mr. U. T. explained and demonstrated the game to them. After a lengthy explanation, the children were d ded into groups, given stones and set free to begin this new game. By the puzzled expressions on the children's faces and the blank look in their eyes, it soon became apparent that many groups were having difficulty. At this point, Mr. U. T. rushed to the aid of several students, explaining once again in Dzongkha the method of Apeygodo. However, many children still appeared confused and frustrated, so the game was stopped and Mr. U. T. and the researcher decided to simplify the rules for the next day and try again.

Apeygodo was re-introduced with fresh, simple rules the following day but to no avail. The game proved to be too difficult for this PP A class. Coincidently, the researcher happened to be passing another PP class not long after visiting Mr. U. T.'s class, and oddly enough this other PP class was playing the same game of Apeygodo. With anticipated excitement, the researcher entered the classroom and found the

children, who incidently were older students, with some repeating PP several times, playing the game with the zeal and vigor which could not be mustered in the younger, more immature PP A class.

Another game called "Yam", based on a traditional gambling game, was also introduced to Mr. U. T.'s class. The game was modified to use "spinners" in place of dice. The spinners were previously constructed by the trainees, from pieces of cardboard with numbers on the corners, and a stick piercing the centre of the cardboard.

The children were divided into pairs and given one spinner, one can of stones and two pieces of paper. The children were instructed to count the correct number of stones after one spin and then to record that number on a piece of paper. Their bright, shining eyes eagerly waited for the spinner to rest so the exact number of stones could be counted. The children thoroughly enjoyed watching this twirling object which displayed the numbers to be used in their mathematical calculations. A twist of the stick and a second spin revealed the number to be added to the first and then both groups of stones would be united to obtain the final result.

Mr. T. N. was continuing the topic of measurement and it was decided to use this concept to construct the court used in a popular Bhutanese game called "Hand-Touch". This game will be described in detail in a future chapter. The researcher and Mr. T. N. felt the transfer of measurement to the children's play, specifically the Hand-Touch game, was very successful.

Another game called "Fire on the Mountain", was also used with Mr. T. N.'s class. This game was taken from an activity taught at the recent NAPE training session in February 1987. The children would run around and around an imaginary mountain

until the caller would bellow a number. Upon hearing the number, the children could be seen squealing with delight as they raced to group themselves into the number which was called. The groups were then used to introduce multiplication facts through the repeated addition process. Again, this game will be discussed in more detail in the analytical chapter of this dissertation.

Another indigenous game called "Boodeem" (phonetic English spelling of Dzongkha word) was used with Mr. U. T.'s PP children. A detailed account will be given at a later time in Chapter Six. This game, as most Bhutanese games, involved stones which were always readily available. Ten stones were given to each pair of students and the game began with little explanation as Boodeem was a very popular game among the children.

Small clusters of children could be seen sprinkled around Mr. U. T.'s bare classroom floor, tossing and catching the stones on the backs of their hands in an intricate sequence. The children took turns and at the end of a complete round they would record how many stones each had gathered and then add these numbers to get the sum, which was always equal to 10.

Mr. U. T. was constantly squatting or kneeling beside the children, offering smiles of encouragement, words of praise or assistance with the recording procedure. Boodeem was very successful in integrating mathematical skills with a fun, challenging game which the children adored to play.

The "multiple game" was another game which was used in teaching multiplication to Mr. T. N.'s class. The class was divided into two, with one-half remaining with Mr. T. N. in the classroom, while the other half followed the researcher into the library for instruction.

The word "product" was introduced in the mathematical sense. The researcher used examples such as 3 x 1 = 3; 3 x 2 = 6; 3 x 3 = 9; as well as expanded notation (3 x 2 = 2 + 2 + 2 = 6) on the blackboard. After a few more examples, the multiple game was introduced. The researcher had all 17 children sit around one large, wooden table. The object of the game was to replace the multiple of a particular number with a clap of the hands. For example, the number 3 was chosen, so each student began by counting one number serially around the table and when a multiple of 3 was to be said, that student would replace the number by clapping. The game continued with the children cautiously saying their number or clapping loudly for their turn. If a classmate made an error the tension was released with good natured hoots of laughter from the other children. The game proceeded merrily making use of the numbers 4, 5, and 6 as factors.

Phase IV: 4 July to 9 August 1987

July 1 began a new academic year for the teacher trainees at the TTC/DS. As a result, during this five week phase a new group of trainees (XII batch) was introduced to the training centre as well as to the research. This group of 29 young Bhutanese adults assisted with one lesson at the end of this particular phase. The researcher decided to involve this new group of trainees because the XI batch, now in their second year, would soon partake in an eight week practicum. Beginning with the next phase, the group of first year trainees (XII batch), would be actively involved with the children of PP A and II B throughout the remainder of the data collection.

The researcher observed four lessons taught by the trainees for each class and four follow-up classes instructed by Mr. U. T. and Mr. T. N. The topics during this phase were multiplication for II B while PP A continued addition of single digit numbers. Again, Mr. U. T. and Mr. T. N. decided to use a medium high in gross motor activity for the teaching and reinforcement of the mathematical skills taught.

Boodeem, the stone game mentioned previously, was still played enthusiastically by the children of PP A. The young students never seemed to tire of this game and played endlessly during class time as well as in their free time. As a result, their skill in adding single digit numbers and recording their results improved greatly.

The trainees (XI batch) and Mr. U. T. also focused upon a complete review of making and recognizing numbers. The successful techniques of stone and sand formations, and the kinesthetic application of drawing numerals in the air or on the children's backs were utilized.

Mr. T. N., while instructing his class in multiplication, involved stones as the concrete objects to group in a given problem. Through repeated addition the children could readily see the mathematical logic of counting stones into the necessary groups indicated by the multiplication question, adding up the stones and arriving at the result. The children were also instructed to record the problem and the result into their exercise books.

Fine motor skills were also stressed with Mr. T. N.'s II B class in the construction of multiplication charts or grids, which could be used at a later time when the children wished to verify their multiplication tables. The children measured and marked off a square on their paper. Then they divided the square into 10 equal parts,

vertically and horizontally, ready to fill in the multiplication tables from 0 to 9. A constant murmur of chattering voices could be heard as the children worked diligently at this fine motor activity.

The researcher will now describe in detail two lessons, both involving the XI batch of trainees with either Mr. U. T. or Mr. T. N.'s classes.

Mr. U. T.'s Class, the Trainees and the Number Line. As well as the game of Boodeem, addition of single digit numbers was taught through the use of a number line to the PP A class. The trainees (XI batch) and the children were grouped at a ratio of 1:2 or 1:1 and everyone marched off to the football, basketball or volleyball area. Each pupil, with the guidance of a trainee constructed a large number line in the dirt. The PP A children used sharp rocks or pointed sticks to carve their line into the warm, moist earth. Fortunately, a gentle monsoon rain from the previous evening, had left the ground damp and free from dust.

The children chattered happily as they marked off their number lines into 11 equal parts. Using their sticks or stones, the children dug the numbers, from 0 to 10 into the damp soil beneath the appropriate mark on the number line.

The trainees then gave simple addition questions to their young pupils (2 + 3; 4 + 2; 5 + 3; etc.). The children would begin by standing on 0 and by either jumping or stepping, moved the correct number of places, as indicated by the trainee. The trainees soon discovered the activity worked best when the children would stop after moving to the first addend, say "plus" and then continue on to the second addend to reach the sum. The trainees would reinforce the concept by repeating the question and result for example, 4 + 3 = 7, when the child had completed jumping.

All over the sprawling grounds, the PP A children could be seen hopping like frogs or rabbits on two feet, to reach their final destination. Other motor patterns included hopping on one foot, jumping sideways, and skipping. The children expressed their delight in the activity by laughing and smiling happily as they bounced along their number lines.

Mr. T. N.'s Class, the Trainees and Multiplication. While focusing upon multiplication the trainees (XI batch) decided to take Mr. T. N.'s class outside. The researcher, prior to class time, had discussed with the trainees the manner in which the lesson should be structured. The children and the trainees, divided into a ratio of 3:2, immediately sprung into action after claiming their space on the volleyball, basketball or football grounds.

The lesson involved having the children perform a gross motor activity to complement a multiplication table. For example, if a trainee chose the four times table, the children would do some form of gross motor activity four times. Upon completion, they would state 4 into 1 is 4. Then continue repeating their pattern in groups of 4, stopping after each set to announce the appropriate table (4 into 2 is 8; 4 into 3 is 12; etc.) to the completion of that table (4 into 9 is 36). It is important to note that in Bhutan, 4 "into" 2 has the same meaning as 4 "multiplied by" 2. The exact origin of this operational expression is unknown to the researcher.

In one corner of the dusty football field, a trainee from southern Bhutan was using a graceful Nepali dance step to carry out the 3 times table. Close to the river's edge, a male trainee demonstrated aggressive arm thrusts taken from the martial arts, to show his group of children the movement they would imitate. The researcher caught an

interesting movement from the corner of his eye and noticed another group of II B children, springing onto their hands, doing cartwheels.

Other groups of children could be seen doing toe touches, jumping jacks, and bunny hops. The trainees reinforced the purpose of the activity by having the children repeat the appropriate multiplication table after each set of actions. The children's eyes sparkled with anticipation as they waited for the trainees to announce the next movement and table to be executed. The researcher could readily see how the children loved to be out of doors and given the freedom to move and use their youthful energy in a structured but creative manner.

The lesson proved to be a unique example of how gross motor activity could be used in reinforcing the multiplication tables. The trainees concluded that it was imperative to state the appropriate table after completing each set or else the activity became a lesson in physical exercise with no relation to the concept of multiplication.

Phase V: 10 August to 8 October 1987

This eight week phase introduces the first year trainees (XII batch) as the sole facilitators for this research. As previously mentioned, the second year trainees (XI batch) were involved in a major practice teaching assignment; therefore, Phase V is characterized by the XII batch of trainees along with Mr. U. T. and Mr. T. N., working with PP A and class II B.

During this phase the researcher observed seven lessons by the teacher trainees with both PP A and class II B and five follow-up sessions, each, involving Mr. U. T.

and Mr. T. N. This phase, longer than previous phases, was more difficult to carry out due to extenuating circumstances affecting the normal school day.

The Bhutanese school year is often disrupted due to unannounced holidays (decided upon by the Dzongda of each district). On several occasions, the researcher would arrive at the school to begin the day only to find a holiday had been announced sometime the previous evening and all the children were sent home. Other common disruptions were the use of class time to prepare for special events such as rehearsing for a "march pass" for educational week or cleaning the grounds of the school in preparation for an official visitor.

Lessons plans and previous preparation, regarding the collecting of data, often had to be postponed and rescheduled during this phase. On one occasion, Mr. T. N.'s classroom was used as sleeping quarters for class VI students from another school during the regional finals for National Education Week. Also, during this time, Mr. U. T. and Mr. T. N. had to make unscheduled, official trips to the capital city to purchase equipment or collect materials. These unexpected breaks in the daily schooling are typical and very much a part of the way of life in Bhutanese schools. Although frustrating, one must accept this cultural necessity and try to put the ingrained western value of time into another perspective.

Fortunately, it was not very difficult to reschedule the lessons to be taught by the trainees or Mr. U. T. and Mr. T. N. The flexibility of the class teachers and students is also a characteristic of the Bhutanese school system. They simply take change or disruption in their stride and carry on regardless. Even the small PP A children exhibited their ability to handle new situations with ease as they responded very well to the new group of trainees, after a very brief introduction.

Ironically, Mr. T. N.'s class II focused upon the mathematical concept of time as well as fractions and the geometric concept of shape. The Pre-Primary A class continued with addition and were introduced to the subtraction of single digit numbers. It is important to note that subtraction is not part of the syllabus for PP in Bhutan. However, Mr. U. T. felt his class could meet the challenge of subtraction due to the success they were experiencing with addition.

The trainees (XII batch) were very responsive in their attempt to teach both classes of children. Under the guidance of Mr. U. T. and Mr. T. N., they used fine and/or gross motor skills in all the lessons taught. Singing, once again, became a part of the math classes taught to PP A and class II B.

Songs were used to focus on fractions with Mr. T. N.'s class while the PP A children sang songs to refresh their counting skills using ascending and descending order. The number line was once again used effectively in adding single digit numbers and was further utilized in the introduction to subtraction of single digit numbers as was the versatile game of Boodeem. A new, board game called "Pema Lotto" was introduced to PP A by the trainees (XII batch) to focus upon addition and later subtraction of single digit numbers.

The trainees made use of sticks and the carved images of clocks in the ground to help the class II B children understand the concept of time. The trainees also introduced fractions to Mr. T. N.'s class through the use of the game "Am I Right?" while Mr. T. N., with a complementary follow-up, brought out scissors, paper and scales to further instruct the same concept. The game of Fire on the Mountain was used once more but this time to reinforce the geometric concept of shape to class II B.

Two lessons will now be described; one involving each class of children taught during this phase.

Mr. T. N.'s Class, the Trainees and Time. The trainees (XII batch) were Class II B's tutors for a lesson focusing upon time. Previously, this concept had been introduced by Mr.T. N. a few days prior to this particular lesson. The researcher, as usual, met with the trainees prior to the class to discuss the strategy which would be utilized. Again it is significant to mention that clocks, as western society knows, have been imposed upon Bhutanese culture. Few homes in Bhutan would be in possession of a clock and if a watch was owned it would probably be of a digital style. So the measurement of time, more than likely was a very new and challenging concept for many of the children in Mr. T. N.'s class, whose parents used their biological clocks as their only time piece.

The trainees and children were divided into a ratio of 1:2 or 1:1. The primary objective of the lesson was to have the children physically manipulate the hands of a clock to correspond to a verbal statement of time.

All groups of trainees and children scattered over the football, basketball and volleyball grounds, finding an area suitable for drawing the face of a clock into the dirt. The children, once again, used pointed sticks or stones to gouge a circle into the earth and then systematically recorded the numbers from 1-12 in the appropriate positions. Next two big sticks, one longer than the other, were placed at the centre point of the clock face and used as the hour and minute hands.

After constructing the clocks the activity began by a trainee verbally expressing a statement of time such as "Show me ten-thirty." Then the children, standing in the centre of the circle, would physically move the sticks to the correct position to show

that particular measurement of time. The exercise continued in this manner for the remainder of the forty minute class.

From the researcher's perspective, the children did very well showing the correct time by using sticks and outdoor clocks. However, interestingly enough in the follow-up lesson by Mr. T. N., where the time was shown on the children's paper, many experienced difficulty in "reading" the correct time, as opposed to "showing" the correct time. After pondering this conflict, the researcher decided the children must be able to show the time much easier than reading it due to the complementary relationship between knowing and doing.

Mr. U. T.'s Class, the Trainees and the Game of Pema Lotto. Using the game of Pema Lotto, Mr. U. T. reinforced the concept of addition of single digit numbers with his PP children. The trainees (XII batch) had reproduced and modified Pema Lotto from a manufactured game which had been sent to the school from Canada. Using firm pieces of cardboard, the trainees had constructed numerous cards (12 cm by 10 cm) dividing them into 12 equal parts. In each small box a digit from 0-10 was randomly placed. Also included in the game were many small rectangles each having a single digit addition problem on one side. Groups of three or four children, each having a large card on their lap, would sit in a circle with the small rectangles, turned problem-side down, in the centre. Turn by turn, the children would chose a problem, decide on the answer and see if the number was on their large card. If it was, then the spot on their large card was covered with the rectangle, if the correct answer was not on their card the child would return the small rectangle to the same spot, face down, on the floor. The game continued until the winner was decided by filling up all the squares on his card.

This game was used several times by the trainees as well as Mr.U. T. for the follow-up lesson. The researcher observed Mr. U. T. reviewing addition of single digit numbers. The game was played in Mr. U. T.'s classroom since the weather was not suitable to go out of doors. The young PP A children were divided into groups of four and instructed to sit in a circle formation on the crowded classroom floor. As they proceeded to play Pema Lotto, the children babbled noisily in Dzongkha, while trying to help one another solve a problem or while expressing glee as they discovered the correct answer on their card. Throughout the room their voices reverberated until Mr. U. T. expressed a command for silence. The silence, although a welcome relief, did not last very long, as the children soon swung into their chatter once more.

In one corner of the room, a small boy with a freshly shaven head, pondered upon the problem he had chosen from the scattered group lying in the centre of the circle. Using the stones, which were piled beside him, he counted out the correct numbers, grouped them together and added them to arrive at the result. Next, he carefully checked his large card to see if the number was there. He lifted his bald head and the smile on his face revealed that he had found the answer on his card and the turn went onto his classmate.

Mr. U. T. roamed throughout the class, pausing to check on the groups to see their progress, or kneeling beside his small students to offer further instruction. The lesson continued in this fashion until the ring of the gong was heard, signifying lunch break.

Phase VI: 12 October to 24 November 1987

This seven week record represents the final phase of data collection. The second year trainees (XI batch) returned from their practicum and as a result both groups of trainees were involved in teaching the children during this phase of the study. The researcher, for consistency purposes, decided that the second year trainees (XI batch) work solely with Mr. T. N. and his class II B, while the first year trainees (XII batch) instruct Mr. U. T.'s PP A class.

It should be explained that the actual collection of data concluded by November 24, 1987 in spite of the fact that the Bhutanese school year did not officially finish until December 18, 1987. As mentioned in the previous phase, many school days were used in preparation for special events which also affected the typical school pattern. Such was the case at TTC/DS as formal classes finished by the third week of November. A one week review period was granted prior to the final examination schedule which began the first week of December.

Following the examinations, attendance at the school was sporadic since class teachers used school days to evaluate examinations. During the second week of December, all teachers, trainees and students were busily preparing for numerous special events. A sports day was held for all children, as were class picnics, and rehearsals of presentations for the annual celebration of National Day on December 17, 1987.

The researcher observed six lessons involving each group of trainees and children, and five follow-up sessions by each class teacher. Mr. T. N. began the topic of measurement with his children which included the concepts of area, perimeter,

volume, capacity, and weight. The children used indigenous forms of measurement such as hand spans and finger widths to measure the perimeter of various objects within Mr. T. N.'s classroom. The II B students placed stones, the indispensable teaching aid, inside containers of different sizes to discover the difference between capacity and the previously taught concept of area. Volume was illustrated by having the children use water to fill containers as well as something solid like stones or dirt. Fine motor skills were always called upon, especially when constructing cubes and cuboids from pieces of paper.

The children exhibited a strong intuitive sense for estimation. Whether the pupils were lifting a classmate to see how much one weighed or deciding upon the distance from one tree to the other, their "guesses" were always very close to the exact measurement of the object.

During the VI phase, Mr. U. T. concluded his instruction of addition and subtraction of single digit numbers and like Mr. T. N. moved onto the topic of measurement. One of the concepts covered by the trainees (XII batch) and the PP A children was weight. As one of the activities, the children distinguished between light and heavy, by lifting two different objects. Gross motor skills were used to introduce the idea of measuring distances. The children, grouped in pairs, did standing broad jumps, then checked to see who had jumped the longer distance. It should be noted, as with any lesson involving the young PP children, language became a fundamental lesson as well. The children, quickly understood new English words, as they were demonstrating the meaning of the words through their movements.

The game of frozen tag was used to help illustrate the meaning of area. A detailed description of this activity will follow shortly.

The winter season was fast approaching the small town of Paro and as a result the majority of the classes taught by Mr. T. N., Mr. U. T. and both groups of trainees were instructed outside. In fact, many of the other classes from the Demonstration School were found out of doors. The classrooms had no form of heating other than the sunshine, so one could find numerous deserted study rooms and few vacant sunny spots outside on the school compound.

The researcher will now give a detailed description of two lessons taught during this phase. One lesson involves Mr. U. T.'s PP A children and the first year trainees while the other delineates a follow-up lesson by Mr. T. N.

Mr. U. T.'s Class, the Trainees and Area. As previously mentioned, the first year trainees (XII batch) introduced the concept of area, through the game of frozen tag, to the class of PP A.

Initially, the researcher and the trainees reviewed the rules and structure of frozen tag and discussed the game's relationship to understanding the mathematical idea of area. One of the most important objectives of this game was to help the young scholars understand that area was a complete surface or space, not simply a formula (A = L x B; Area = Length x Breadth) to be memorized.

The trainees, after dividing into four groups of seven, played the game in the classroom to ensure everyone understood the rules. After this trial run, it was decided that there would be two "cats" or chasers, one trainee and one PP A child, in each of the four groups. It was also decided that during the first part of the game, if a "rat" was caught he would "freeze" in a long shape and in the second half of the game, the shape would be short. When everyone was clear on the activity, the trainees proceeded to the assembly ground to meet Mr. U. T.'s children. The PP A children were divided into

four groups of eight, and then each set joined one of the trainees four groups. In total each group, trainees and children, comprised fifteen players.

The groups quickly spread out over the volleyball, football, and basketball grounds. The trainees then explained the rules of the game and with stones made an outline on the ground to represent the boundaries where the players could run. The trainees could be heard telling the children that they must only run inside the area marked by the stones. Thus, the reinforcement of the meaning of area was shown through this game. Usually one trainee from each group was assigned as the group leader. That trainee's responsibility was to explain the rules of the game as well as the shapes to be made. The other trainees within that group would assist by demonstrating the shape or pointing to the perimeter of the area used in frozen tag.

Although some initial confusion was exhibited concerning the "rats" role of unfreezing their teammates, after a further explanation all participants could be seen scampering inside the designated play area. Squeals of excitement were heard throughout the compound as the cats came close to or caught the rats in their group.

One set of participants decided to extend the boundaries of their court because after playing the game for several moments they found that it was too small an area for their movement. It was decisions such as these, to either modify or change a learning situation to meet the needs of the group, which further developed the role of the trainees as educators. They learned that sometimes when working with children, changes must be made immediately during the activity in order to make it effective.

In one group, the researcher noted two lively cats, always one trainee and one child, dashing after the other 13 members in the group. The rats were darting around and beside their already frozen teammates in an attempt to outsmart the crafty cats. One

small girl, found herself trapped in a corner, unable to escape the preying cat, who soon tagged her. She immediately took the position of a long shape with arms reaching to the open blue sky, high above her head. Her dark eyes quickly glanced around the court, trying to meet the gaze of a running teammate who could release her from the frozen pose.

Part way through the game the trainees instructed the children to change their frozen forms. Instead of long shapes the group would make short poses, if caught by the cats.

After thirty minutes of almost continuous running the children and trainees appeared to be quite exhausted. They all welcomed the opportunity to sit on the ground to rest at the conclusion of the lesson.

Mr. T. N.'s Follow-Up Lesson and the Construction of Cubes. Mr. T. N.'s follow-up lesson focused upon the construction of a cube and a cuboid from paper. The previous day the second year trainees (XI batch) assisted the children in making cubes. However, this follow-up witnessed the children working independently with only a few verbal instructions from Mr. T. N.

Unlike most of the lessons which were taught outside, Mr. T. N. felt it best to remain indoors so the children could have firm, flat surfaces while constructing their geometric shapes.

Mr. T. N.'s classroom recently received NAPE furnishings and low, blue tables now were clustered in groups around the room. The children sat on the floor with their legs tucked under the table in a crossed position. The walls were cheerfully decorated with various posters and charts made by either Mr. T. N. or the class members.

After drawing the children's attention to the chalk board, Mr. T. N. drew the pattern of a cube and cuboid, which the children would use when constructing the shapes at their tables. The children were extremely busy measuring, erasing, and measuring again so their cube or cuboid would be exactly the same as the diagram on the board. Finished samples of a cube and a cuboid were on the tables, the result of the trainees assistance the previous day. Often the children would pick up the finished products to check on the direction in which their projects were heading.

The researcher was suddenly aware of the silence in the classroom. Usually a murmur or buzzing of voices was present when the children were working indoors. However, this particular lesson was very quiet, with only the rustling of papers, snipping of scissors and occasional coughing or stirring of the children.

Mr. T. N., after giving general instructions to the class concerning the measurements to be used, began walking around the classroom, weaving between the low tables and stopping to offer assistance to some or checking the measurements of others.

The class was intense in fine motor activity. The dark heads of the Bhutanese children were bent low over their work, marking with their stubby pencils, checking and perfecting their drawings like true Bhutanese artists.

One boy finished his diagram of the cube much quicker than the rest and was skillfully using a pair of scissors to cut his efforts from the paper. Next, he carefully folded the sides upwards in preparation for pasting them together to achieve the final product. Other children at his table glanced enviously at his work then returned to their own projects with concentration and determination.

At the finish of the forty minute lesson many children had completed their cubes and cuboids. A few students were still working and seemed reluctant to put away the activity to complete at another time.

Summary

As stated in the beginning of this chapter, the main purpose of this case record was to transport the reader to the research setting so that the reader could be given the opportunity to perceive the situation as the case researcher did. The researcher has given a detailed description in an effort to portray the context in which the investigation was undertaken. In addition, this description has created a context for the theoretical analysis contained in the next chapter.

Over the period of one Bhutanese school year, forty-four lessons involving the teacher trainees (XI and XII batches) and forty-seven by Mr. T. N. and Mr. U. T., totalling ninety-one sessions, were observed by the researcher. Almost all of the mathematical lessons witnessed were high in movement activity, either fine and/or gross motor. Also, many mathematical concepts were instructed by using songs, games, and movement patterns to utilize the inherent interest which the children had in their own play.

The case record was characterized by unique occurrences throughout the school year and, consequently, was divided into six phases. Phase I was an introduction to TTC/DS, Mr. T. N. and his class II B as well as Mr. U. T. and his PP A children. During Phase II, the collection of data began with the XI batch of trainees assisting

both Mr. T. N. and Mr. U. T. This batch of trainees were the only student teachers present at TTC/DS at this particular time.

Phase III reveals the researcher observing Mr. U. T. and Mr.T. N. with their two classes. There was no involvement from the XI batch of trainees as they were preparing for their final examinations. Phase IV was characterized by the return of the XI batch of trainees, now in the second year of their program, and by the introduction of the new group (XII batch) of student teachers to the study. Mr. U. T. and Mr. T. N. remained constant in their roles during the data collection.

During Phase V the new group of trainees (XII batch) were the sole participants from the training section since the XI batch were completing their final teaching practice. Phase VI brings closure to the case record as both groups of trainees along with Mr. T. N. and Mr. U. T. were observed until the completion of formal classes for the 1987 academic year at TTC/DS.

In conclusion, this case record was based upon detailed field notes and audio-visual data, which were recorded during the actual period of research.

CHAPTER SIX

ANALYSIS AND DISCUSSION

The strategy of the interpretation focuses upon the use of the analytical term: propositional theme. Three such propositional themes were derived from the data. As previously stated, developing a theme involves interpreting the data by searching for recurring regularities, and it may be conceived as a behavioral pattern that actually characterizes the case study. Additionally, the term propositional is used in its mathematical sense and denotes a formal statement of truth to be demonstrated. Thus, in the context of this investigation, a propositional theme is a recurring behavioral pattern which denotes a fundamental truth that will be shown through demonstration to be an actualization of complementarity.

This progresses the interpretation to its final stage of analysis, that being the development of and building upon the principle of complementarity as a theoretical framework for a form of pedagogy, that attests to be an exemplification of ethnomathematics.

Explicitly the analysis for each propositional theme follows this pattern: (a) the propositional theme is stated, (b) the working hypothesis is developed through establishing a connection between the properties of the theoretical research and the pedagogical activities, (c) a demonstration of the working hypothesis is depicted through descriptive accounts, and lastly (e) a discussion is presented focusing upon the theoretical implications of the propositional theme.

The chapter concludes with a section centering upon indicators of student achievement such as participant self-reports, that attest to the mathematical skills and knowledge gained by the children of this study.

Propositional Theme I

Complementarity: The Voices of Bhutanese Children

Development of the Working Hypothesis

As the religious Bhutanese historian Rigzin Dorji (1983b) has stated, religion plays a significant part in almost every single facet of life within Bhutan.

> From archery contests to the painting of murals, from the phenomenon of birth to that of sickness and death, almost each significant moment in the life of a Bhutanese is, in one way or another, linked with religion. (p. 40)

A characteristic of any religious event or festive ceremony in Bhutan is the recitation of Buddhist prayers, the chanting of religious mantras, and the singing of Buddhist songs.

Further, in an article entitled "Spiritual Living: Enthusiastic Enjoyment--Daily Life and Entertainment", Dorji (1983a) speaks of the customs that are involved in the building of a house in Bhutan. When a house is built, it is traditional for neighbours to assist in the construction. "While the men-folk engage in the more strenuous activities, the women pound mud or help carry it to the allotted places. As in almost every public occasion, these tasks are accompanied by much singing" (p. 8-9). As one can see, any religious event or public occasion in Bhutan is characterized by singing.

Furthermore, archery is the national sport of Bhutan and it is an essential part of most festive occasions. An auspicious ceremony called a *marchang* , in which

offerings are made to local deities, is performed at the archery venue and is accompanied by seven, nine or eleven female dancers (Dorji, 1983a). The dancers provide spiritual support for their own side throughout the contest by dancing to the music of their songs. The musical instrument for all ethnic dances of north-western Bhutan, where the Paro Valley is located, is the human voice. Consequently, it is proposed that the teaching of elementary school mathematics through musical songs will be an actualization of complementarity because of the complementary relationship between the culture of Bhutanese children and their school environment.

In addition to the complementary relationship that exists between singing, as a part of Bhutan's culture, and elementary school mathematics, there lies support for this proposal within hemispheric research of the human brain.

To reiterate, it is now broadly accepted that the two hemispheres of the human brain have significantly different functions (Restak, 1984). The left hemisphere is primarily involved with analytical and logical thinking, especially in verbal and mathematical functions (Blakeslee, 1980). On the other hand, the right hemisphere has been characterized as non-verbal, intuitive, spatial, musical (Bogen and Bogen, 1969). In summary, literature reviews focusing upon the functions of the right and left hemispheres have been consistent in their conclusions. For example, Harris (1979) states that:

> Direct measures of cerebral hemisphere functioning indicate that the left hemisphere is dominant for speech, sequential processing, and logical thinking in nearly all right-handers and the majority of left-handers, while the right hemisphere is dominant for holistic or Gestalt perception, nonverbal reasoning, and music. (p. 57)

More specifically, studies focusing on hemispheric specialization have discovered a right hemispheric superiority for singing, and the musical qualities of

melody, pitch and timbre; left hemispheric superiority has been shown for the analytical musical quality of rhythm (Bever & Chiarello, 1974; Gordon & Bogen, 1974; Goodglass & Calderon, 1977; Gates & Bradshaw, 1977). For example, in the Gordon and Bogen (1974) study, when the right hemisphere of subjects was anesthetized, songs were sung in a monotone manner, lacking any form of proper pitch. These researchers concluded that the right hemisphere played a more significant role than the left in the behavior of singing. Harris (1979) discovered that the left ear (right hemisphere) was superior to the right ear (left hemisphere) in the recognition of musical notes and melodies. In addition, Borod and Goodglass (1980) also ascertained that the left ear (right hemisphere) has an advantage for the musical song quality of melodies.

More recently, and to summarize, in an article entitled *Hemispheric Specialization and Functional Plasticity During Development* Levine (1984) confirmed the above by stating:

> It is now widely accepted that the left hemisphere is specialized for analytic, linguistic functions while the right hemisphere is specialized for more holistic visuo-spatial and tactuo-spatial functions as well as the perception of *tonal patterns* and *environmental sounds* [italics added]. (p. 78)

Furthermore, what has emerged in the theory of hemispheric specialization is the conception that the cerebral hemispheres function in a complementary manner (Capra, 1982; Levine, 1984; Ornstein, Thompson & Macaulay, 1984). Rather than viewing one hemisphere as being major as in the theory of cerebral dominance, scholars are proposing that the intuitive, holistic thinking right hemisphere complements the analytical, linear processing left hemisphere in our perception of the world.

Based upon the theoretical implications presented in Chapter Two and what has been presented above, it is hypothesized that the teaching of elementary school mathematics through musical songs of Bhutanese children will be an actualization of the principle of complementarity. This analysis of the data proceeds by revealing descriptive accounts that demonstrate complementarity through a pedagogical practice that involves learning mathematics via musical songs.

Demonstrative Accounts

Mr. T. N.'s Children, the Trainees and Songs of Place Value. On 30 April 1987 during the first class period, the researcher and the trainees (XI batch) met and discussed mathematics methodology, specifically the teaching of place value and the function of the decimal point with money. Afterward, the trainees were divided into two groups, A and B. Group A was subdivided into two groups with the task of each subgroup creating a song integrating the decimal point, place value, and money (rupees and paise). These groups would teach their song during the second half of the period with Mr. T. N.'s children. Group B was divided into six pairs and discussed an activity in which each child of their group would represent a digit and change places in order to alter the value of the number.

Since it was raining that day the following four areas were utilized for instructional purposes: (a) Mr. T. N.'s classroom, (b) the library, (c) the veranda, and (d) the trainees classroom. Each pair of trainees had six children to work with in their respective areas, and each pair approached the methodological problem similarly by having the children physically change places in order to create the numeral given.

After 25 minutes the trainee groups, who were to teach the song that they had created, subdivided into four groups and subsequently went to each of the areas for

teaching purposes. One group had created the following song which was sung to the tune of "I'm a Little Teapot."

Zero to Nine

We are learning about maths, 0 to 9
If we learn it nicely, that's very fine
Oh! When we use the decimal, we get confused
But the decimal there can be used
Here is an example showing to you
1.25, example for you.

The other group taught the following song in which the lines within parentheses were each sung twice:

Meeting Place is Decimal Point

If we move figure one place left
(It will be 10 times big)
If we multiply that by 10
(It will move, to next place value)
If we divide that by 100
(It will move to right place value)
Meeting place is decimal point
(For it separates rupees and paise).

Mr. T. N. decided to continue singing the songs during the next period within his classroom. The researcher observed this singing period and the lesson concluded with the children copying the songs into their exercise books while pronouncing and singing the lyrics.

Mr. U. T.'s Children, the Trainees and Counting Songs. On 24 August 1987 the first year trainees (XII batch) taught the following songs to Mr. U. T.'s pre-primary (PP) children: (a) Ten Little Bhutanese Children, and (b) Ten Green Bottles. The trainees were divided into four groups having two instructional divisions within each major group, who, in turn, were each responsible for teaching one of the songs listed above. Mr. U. T. also divided his children into four groups, each group

proceeded to one of the four instructional areas which included: the trainees' classroom, the library, the assembly area, and Mr. U. T.'s classroom.

With the guidance of the trainees the children sang these two songs over, and over, and over again. Standing in lines shoulder to shoulder, and with arms held high, the children attempted to co-ordinate their hand movements with the lyrics which they had mastered well. However, a pedagogical problem was noted by the trainees and discussed with the researcher following the lesson. The trainees observed that the children had difficulty in co-ordinating the fine motor hand activities with the lyrics of the songs.

Consequently, the trainees made the following pedagogical recommendations regarding the teaching of songs to Bhutanese pre-primary students: (a) the children should master the lyrics and tune of a song before learning the actions, and (b) the children should utilize whole body actions (gross motor) instead of finger actions (fine motor) to complement the lyrics. For example, in the song Ten Little Bhutanese Children, Mr. U. T.'s children eventually learned to begin in a squatting position and stand up as their corresponding numeral was sung and, subsequently, kneel when the song progressed to its second verse.

Mr. U. T.'s Children and Counting Songs. On 19 November 1987 the researcher visited Mr. U. T.'s class for the purpose of observing a follow-up lesson, focusing on the singing of songs, related to the mathematical operations of counting, ordering, and sorting.

Initially, Mr. U. T. divided his class into three groups of ten, such that two lines were sitting one behind the other while facing the third line. While speaking in Dzongkha, Mr. U. T. asked the children to stand up and sing their favorite tune, "I

Can Count from 1 to 10." Following this, and beginning in a squatting position, each line of children sang this song.

The lyrics of "I Can Count from 1 to 10," a song which was sung by different groups of children every day at TTC/DS during the 1987 school year, follows:

I Can Count from 1 to 10

One and one--two
Two and Two--four
Three and three--makes six for us.
Four and four--eight
Five and five--ten, little fingers in my hand
I can clap, clap. I can snap, snap
I can roll them all about.
See my fingers, happy dancing,
I can count from 1 to 10.

Next, each group of children sang "Ten Little Bhutanese Children" and learned to stand or squat when their specific numeral was called. Following this, a similar procedure was conducted in the singing of "Ten Green Bottles." This behavior, on the part of the children, revealed that they were learning the ethnomathematical practices of counting, ordering, and sorting while singing these songs. Subsequently, and while standing, all the children sang "Six Little Ducks" prior to repeating the song in a circle formation. Remaining in that formation, the children then sang "Here We Go Loop de Loop." After more than 30 minutes of singing in unison with the same vibrancy and energy that began the class, the children concluded by singing, "Here We Go Round the Mulberry Bush."

Discussion

Inherent within the everyday life of Bhutanese children is the act of singing, of hearing, of reproducing sound. From the recitation of Buddhist prayers, to the

chanting of mantras, to the singing that accompanies Bhutanese dance, Bhutanese children have developed a unique skill at being able to receive and reproduce sound.

Over and over again this unique characteristic of Bhutanese children has been commented upon by educational consultants and pedagogues that have visited and worked in Bhutan. Wood (1987), an English curriculum consultant, stated that Bhutanese children have developed a facility for singing and the reproduction of sound as well as being accomplished memorizers. He indicated that educators should tap this phonetic talent and memorization skill. Further, in response to the question "What are the specific talents (qualities) of Bhutanese children?" O'Caside (1987), a language arts specialist, made the following statement: Bhutanese children have a great knack at picking up languages. It is a talent, but it reflects more their attitude toward languages. Finally, F. Pommaret-Imaeda (1987), an anthropologist and linguist, stated that Bhutanese people have a wider phoneme range compared to persons who speak only English, for example.

Consequently, by teaching elementary school mathematics through the songs of Bhutanese children, a bridge has been created between the culture of these children and the world of mathematics. Thus, complementarity has been demonstrated between the everyday life of these children and their school environment. It is proposed that this bridge heeds Barcello's (1981) concern that children in the Third World cannot see how the mathematics they learn in school relates to the world in which they live. Furthermore, complementarity has been demonstrated through a form of pedagogy that attests to tap the predominant functions of the two hemispheres of the human brain. The very sound of music itself, the tonal quality, has been shown to be a component of music which is primarily a function of the right hemisphere. By

utilizing musical songs as a medium for acquiring basic number facts, pedagogy has been shown to be an actualization of complementarity.

This actualization of complementarity has also had a recursive effect in that the researcher frequently observed and heard children singing songs, that they had learned in school, in the market place of Paro, or on their way to and from school. This exemplifies how the complementary relationship between the everyday life of Bhutanese children and their school environment can be dynamic and interchanging.

The significance of oral recitation in the schooling of Bhutanese children is also demonstrated by several aspects of a typical school day. Each morning at a primary school in Bhutan, the students will gather for assembly, which includes the recitation of a Buddhist prayer and the singing of the National Anthem. Following this, speeches are delivered by two students, one in English and one in Dzongkha. In southern Bhutan speeches are also presented in Hindi and Nepali on alternate days to that of English and Dzongkha. Another example of how oral recitation is a daily part of the lives of Bhutanese school children, is the fact that prior to eating lunch, which incidently is supplied by the World Food Program, all Bhutanese children will chant a Buddhist prayer for up to ten minutes prior to consuming any food.

Instruction in the national language of Dzongkha almost entirely involves choral reading and choral recitation performed in a musical and rhythmical fashion. Lastly, the means by which Bhutanese decode words while reading is based upon sound. When a Bhutanese school child comes to a word that is not known, he or she will spell the word by pronouncing loudly each individual letter. This procedure seems to tap a "sound engram", as frequently the child is able to pronounce the word after decoding it in such a manner. This researcher infers that these children have a

"sound vocabulary" just as children from Canada are thought to have a "sight vocabulary."

In conclusion, it has been demonstrated that Bhutanese school children make use of sound in an intuitive and thus complementary manner in their perception of the world. The voices of Bhutanese children have been shown to be a medium by which they can learn mathematical literacy, just as they have learned religious prayers and the languages of their culture.

Propositional Theme II

Complementarity: The Indigenous Games of Bhutanese Children

Development of the Working Hypothesis

As previously stated, the responsibility of educating prospective primary teachers in Bhutan rests with the two teacher training institutions in the country: the National Institute of Education (NIE), Samchi, and the Teachers' Training Centre and Demonstration School (TTC/DS), Paro. In order to educate prospective primary teachers in a more standardized manner, and to complement the curriculum changes occurring within Bhutan's primary education system, NIE and TTC/DS jointly planned and implemented the same primary teacher education curriculum in July of 1986. This core curriculum is outlined in the document *Primary Teacher Certificate Course: NIE, Samchi and TTC, Paro, July 1985*. In this curriculum and within the Mathematics syllabus under the section entitled "Activities for Maths Teaching," the following is stated:

> (b) Outdoor Activities: how to modify outdoor activities learnt in pedagogy for the teaching of maths. The following activities will be dealt with: e.g. sandplay, mudplay, stoneplay, rhythm and movement, circle games, running games, throw and target games.
> (c) How to modify popular children's games for the teaching of mathematics. The following games will be dealt with: e.g. marble games, archery, khuru, dego, stone games. There are double purposes to these activities: (i) to develop motor skills and muscle coordination; (ii) to learn mathematics through the playway method. (p. 59)

The vital significance of this recommendation by Bhutanese educators lies in their awareness of the value of play to the growth and development of children (Fishburne, 1985). Children naturally and spontaneously play, and children's games are very much a part of that play. Bells are not needed to begin a day of play nor are signals required to tell the children it is time to stop. Consequently, it would seem logical that educators should tap this vital source of interest in the schooling of children.

Humphrey (1987), who has written extensively on the teaching of the 3Rs through physical education, theorizes that because children are predominantly movement oriented, they will learn more efficiently when physical activity operates at a maximum level in a school subject like mathematics. It appears then that Bhutanese teacher education curriculum developers concur with this scholar.

Further, and again, the use of Bhutanese children's games in the teaching of primary school mathematics displays a complementary relationship between their world of play and their world of school. If Bhutanese children are educated to see how mathematics is an inherent part of their indigenous games, then a bridge shall be constructed between these two worlds that appear to be opposite. By recommending that children learn mathematics through such physical activities as: stoneplay, running games, marble games as well as other traditional games, Bhutanese curriculum

developers are suggesting that children can and should learn mathematics through an ethnomathematical medium.

Inherent within the indigenous games of Bhutanese children lie the ethnomathematical operations of counting, ordering, sorting, measuring and weighing. D"Ambrosio (1981) points out that teachers must adopt a different role in the holistic education of children in the developing world in order to assist children in their perception of reality. This reality for children is what is of value and interest to them; hence, it can be their indigenous games. D'Ambrosio asserts that the teachers role must be one of stimulating critical reflection by the student upon the student's perceived reality.

Metaphorically speaking the role of the teacher advocated by D'Ambrosio (1981) will be the same as the role of the corpus callosum within the human brain. That is, the corpus callosum's major function is to transmit information between the two complementary hemispheres of the human brain, as the function of a teacher shall be to allow the perceived world of children's play to communicate with and be part of children's perceived world of schooling. Thus, D'Ambrosio is proposing what is of most importance for a teacher in the developing world is to be able to sense a child's perception of reality and a child's drive toward action. This chain of reasoning leads D'Ambrosio to conclude that mathematics must be a part of the context in which the child lives or it will become a useless appendix to the educational experience of children.

What becomes so important for Bhutanese children and thus the country of Bhutan, is revealed by the fact that only 1:4 primary school aged children are in school

and of this group, only 1:4 will complete class six; therefore, it is vital that the mathematics that children learn in school can be seen to be a part of their environment.

Turning now to the research on the hemispheric differences in the human brain, it can be shown that a complementary relationship also exists between the subject of mathematics and the games of Bhutanese children. Mathematics is primarily associated with the left hemisphere because of the left hemisphere's analytical, sequential and logical predominance in the processing of information (Restak, 1984). In contrast, the right hemisphere is referred to as being the non-verbal, nonmathematical, minor hemisphere which has its own perceptual, mechanical and spatial mode of apprehension and reasoning (Sperry, 1983). The right hemisphere has been shown to be most adroit for more holistic visuo-spatial and holistic, tactuo-spatial functions, such as mentally walking through a maze, understanding and working with maps, visualizing and recalling faces, and the stereognostic measurement of an object (Levine, 1984; Restak, 1984). (Again, stereognostic refers to the perception of the shape and weight of an object, such as a stone, through the tactile and kinesthetic modalities.) However, researchers have recently discovered that the two halves of the brain work together in all our activities, each contributing their own special skills and thus, complementing each other (Capra, 1983; Levine, 1984; Ornstein, Thompson & Macaulay, 1984; Silverstein & Silverstein, 1986).

In summary, the theoretical implications put forward in Chapters Two and Three and the brief review outlined above have focused upon the complementary relationship between the play of Bhutanese children and their schooling, as well as the complementary relationship between the hemispheric functions of the human brain. Therefore, it is hypothesized that the teaching of elementary school mathematics

through the indigenous games of Bhutanese children will be an actualization of complementarity.

This analysis proceeds by revealing descriptive accounts that demonstrate complementarity through a pedagogical practice that involves Bhutanese children learning mathematics through their indigenous games.

Demonstrative Accounts

Mr. T. N.'s Children and the Game of "Hand-Touch". On 5 June the researcher visited Mr. T. N.'s class in order to record a lesson focusing on the use of the game called "hand-touch", that was to be used for the teaching of linear measurement. Mr. T. N.'s children, both boys and girls, had been observed playing this game before school in the mornings, at interval, after school and even in the marketplace.

Mr. T. N. and the researcher had agreed prior to the class that the researcher would make six diagrams of hand-touch courts that the children would use as plans to guide them in their construction of full sized courts on the soft clay grounds of the football, basketball or volleyball areas.

Mr. T. N. drew a plan of the rectangular shaped court, 6 m by 5 m, on the blackboard including the three parallel internal rectangles, 5 m by 50 cm. Two of these internal rectangles utilized the 5 m edges of the larger rectangle, while the third internal rectangle was placed in the middle of the larger rectangle and parallel to the other two internal rectangles (see Figure 8).

Subsequently, Mr. T. N. divided the class into six groups of six students and gave each group two metre sticks prior to proceeding to the grounds. There each group began to measure and draw a court. The video-tape data of the children constructing the

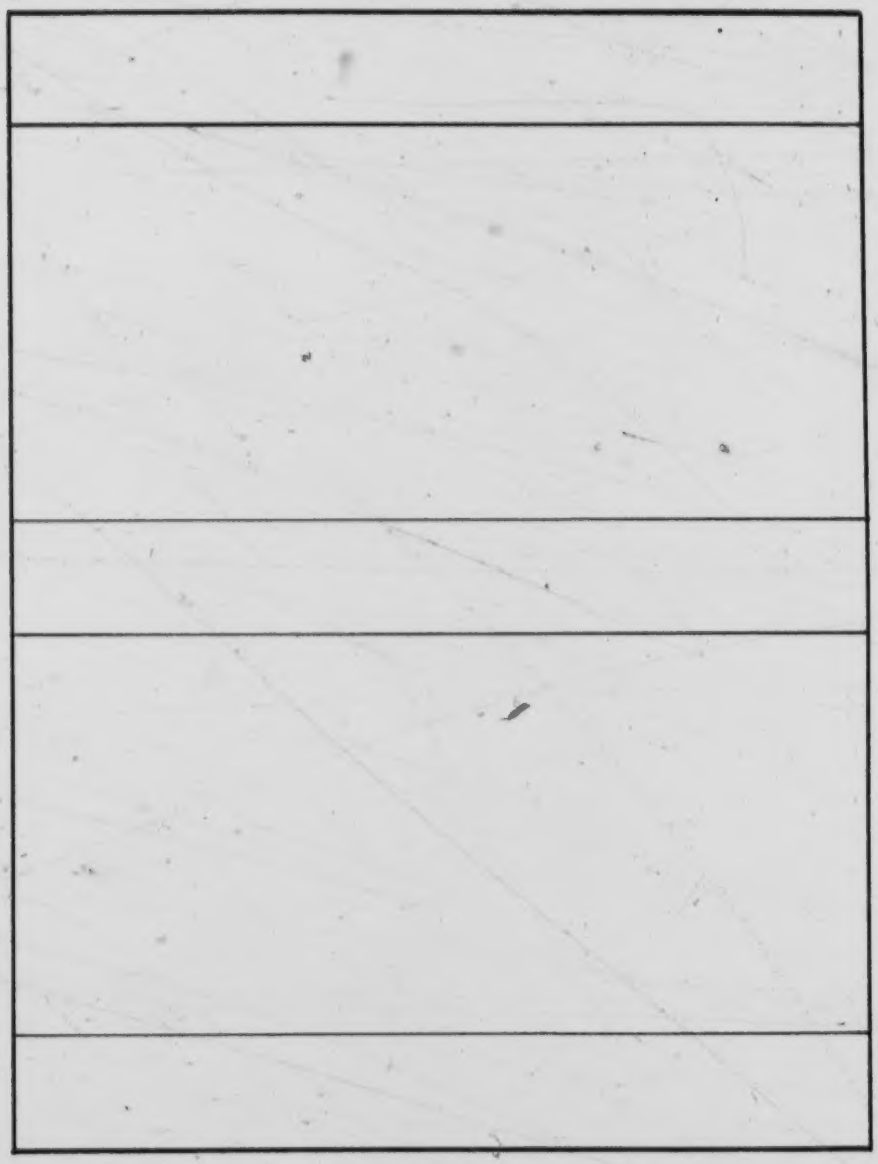

Figure 8. Diagrammatical representation of a "Hand-Touch" court.

courts revealed a high level of co-operation and "time-on-task" by all of the six groups. Each group worked diligently as a team measuring and drawing the courts accurately on the grounds which had been recently softened by an early monsoon rain. Usually, three children used one metre stick to measure and draw an edge as did the remaining threesome of a group. Mr. T. N. could be frequently heard telling the children not to use the metre stick when inscribing the edges. Consequently, the children while working on their hands and knees, used a stone, stick or broken piece of glass to complete their drawing prior to the actual playing of the game.

The video-tape data also revealed that this game is a form of tag game in which one team of three students tries to pass through the court without being tagged by their three opponents who are permitted to only move laterally on the internal rectangles. Mr. T. N. was observed energetically playing the game during the last 15 to 20 minutes of the lesson. The entire outdoor session of constructing the hand-touch courts and of playing the game lasted for over 70 minutes.

Mr. U. T.'s Children and the Stone Game of "Boodeem". For the purpose of assisting his children in learning to add single digit numbers and learning to record the addition algorithm in a horizontal manner, Mr. U. T. decided to make use of a stone game called Boodeem (phonetic English spelling of this Dzongkha word). This game was chosen because many of the pre-primary children as well as some class ones had been observed playing this game in their free non-class time.

On Tuesday, 16 June, Mr. U. T. began by dividing the class into pairs while distributing to each partnership one pencil, ten stones and two pieces of paper. Mr. U. T. had previously indicated to the researcher that he would divide the class according to

intellectual achievement. That is, one child in each partnership would supposedly be better at adding single digit numbers than the other.

Speaking in Dzongkha, Mr. U. T. explained that each child should put his or her initial at the top of one column, and the partner's at the top of the second column. Mr. U. T. or the researcher had written on each piece of paper the word "sum" as the heading for the third column. The children counted their stones while Mr. U. T. checked to make certain all pairs had ten.

The children started to play the game of Boodeem by both children tossing the ten stones separately. The child who caught the most stones on the top of his or her hands won the right to begin the game. The video-tape data disclosed that the remainder of the game primarily consisted of striking one stone with another that had been propelled by the flick of a finger as in the game of "croquinot." A player could not attempt to capture a stone that was less than a finger width from the one that he or she was striking. Thus a custom of the game was for a child always to draw a finger between the two stones before attempting to flick one at the other. The round ended when all ten stones had been collected by one or both of the children. It was at the end of a round that a child recorded how many stones he and his partner had gathered and then added these numbers to get the sum which should have been always equal to 10.

The video-tape data revealed that all of the children enthusiastically played the game and displayed a high level of time-on-task. Further, the majority were successful at being able to record and calculate the sum of their scores. Mr. U. T., throughout the period, moved from one set of children to another squatting beside them, in order to assist with the recording procedure. Sitting on the floor in a cross-legged position, the children tossed, flicked, counted and added the stones for over 60 minutes.

Mr. T. N.'s Children, the Trainees, and the Game "Am I Right?" On Thursday, 24 September, it had been decided that the trainees (XII batch) would use the game Am I Right? as a medium for teaching fractions, specifically eighths, to Mr. T. N.'s children. Lately, Mr. T. N.'s children had been observed constantly playing this game prior to classes in the morning, at interval, after school and in the market place. Since they were studying fractions at this time, it seemed most appropriate to have it become a medium for enhancing the children's understanding of this mathematical concept.

The researcher met with the trainees prior to the lesson and discussed the Am I Right? court and its rectangular shape which is divided into eight equal quadrilaterals. Subsequently, all the participants met in the assembly area and the resulting ratio of trainees to children was either 2:3 or 2:2. As the video-tape data revealed, the children immediately scattered about the playing fields and started to draw the courts on the assembly, volleyball, football and basketball grounds.

Within a few moments all children commenced playing the game, which is similar to "Hopscotch" but much more complicated in its cognitive and motor patterns. Standing alongside the shortest edge, the children faced the rectangular court and tossed their stone on the internal quadrilateral to their left which was closest to them. While hopping and balancing on one foot, the children kicked their stone with that same foot to the next quadrilateral as they travelled up one side of the court and returned "home" on the other side. If they were successful, that is if the stone did not go outside of the main court area or land on a line, the children would start again by tossing their stone on the second internal quadrilateral.

Frequently, the trainees could be heard asking the children what fraction of the total did the quadrilateral represent that they were standing on, after hopping or tossing their stone to that location. That is, if a boy or his stone had travelled to the third quadrilateral then he would state that this location represented three-eighths of the court.

The game continued and the children were next observed hopping on one foot through the eight quadrilaterals while carrying their stone on their arm, hand, or head, or on their other foot. This was done in a sequential order and had to be completed by each child before being able to progress in the game. Next, the children stood with their back to the court and tossed their stone over their shoulder attempting to have it land on one of the eight quadrilaterals. If it did and the children successfully hopped and kicked the stone through the court, they would be awarded that quadrilateral as their house. Again the trainees were frequently heard asking what fraction of the whole does your house represent or if one had three houses, what fraction of the total would one have. Usually, the children were able to answer these questions correctly.

Lastly, before children were permitted to try and win another house, they attempted to walk through the eight quadrilaterals with their eyes closed and their heads lifted toward the sky. As the children stepped, they would say, "Am I Right?" questioning whether they were standing within the perimeter of a quadrilateral. If the children stood outside of the court or on a line, they then lost their turn.

The video-tape data revealed that the children energetically played the game for over 30 minutes and once again displayed a high level of time-on-task throughout the activity. Further, the children exhibited a high participation activity ratio since they were in small groups, which utilized their own playing court. As well, this high activity ratio was a result of these Hand-Touch courts being scattered throughout the

basketball, football, volleyball and assembly grounds. Lastly, the majority of the children were successful at being able to improve their knowledge of fractions through this game.

Some trainees could be seen hopping through the court or tossing a stone, while others encouraged the children to analyze and subsequently verbalize a mathematical reality about a game that the children had intuitively known from the first day that they had learned to play *Am I Right?*

Discussion

Ethnomathematics has been defined as the confluence of mathematics and cultural anthropology (Scott, 1985). The prefix "ethno" can refer to children of a certain age bracket and the root of the word, "mathematics", can be considered to focus upon the operations of counting, ordering, sorting, measuring, and weighing. Thus the term ethnomathematics can refer to how these mathematical operations are inherent within the indigenous games of Bhutanese children.

The Bhutanese children's games of "Hand-touch", "Boodeem", and "Am I Right?" were used as mediums to assist with the instruction of specific topics within the primary school mathematics syllabus. The description of the children playing these games demonstrated how counting, ordering, sorting, measuring and weighing are inherent within them. Complementarity was displayed by integrating the children's world of play with their world of school as well as through a pedagogical process that tapped both hemispheres of the human brain.

However, the ethnomathematical reality inherent within the above games goes much deeper and is much more profound than what has been delineated thus far. Let us focus on the game Am I Right? It was used successfully for teaching the concept of

fractions to Bhutanese children and more specifically these children were led by their instructors to the relationship between eighths and halves. However, by presenting the game as a mathematical activity children were given the opportunity to see other mathematical components and practices within this game. The child began the game by stereognostically measuring the stone as he or she prepared to propel it through space with the intention that it land at a specific point. This is a mathematical task because estimation is used, in attempting to achieve this physical goal, in attempting to have the stone land by throwing or kicking it to a specific point in space.

Lines were drawn, four sided figures were created, a relationship was displayed such that knowledge of the interior, the exterior, and the perimeter determined whether a child progressed. Through playing the game Am I Right?, the children intuitively displayed a highly developed non-verbal comprehension of mathematics. Through playing this game, the children exhibited a complementary form of mathematical understanding.

By analyzing and, subsequently, verbalizing their awareness of fractions as being inherent within this activity, the children were stimulated to critically reflect upon their perceived reality. This was a complementary activity, this was an ethnomathematical activity, but this lesson only began to tap the intuitive mathematical knowledge that a child must possess in order to play the game.

Recall that stage of the game where the child stands with his or her back to the court, tosses the stone over his shoulder, and then attempts to walk through the playing court as though he or she were blind folded. The child must create a visual image in order to solve this visual-spatial problem; therefore, the child must use his right hemisphere in this mathematical task which had as its objective the enhancement of the

understanding of the concept of fractions. Creative problem solving is a result of using both halves of our brains (Blakeslee, 1980). Creative problem solving is a result of using the intuitive and the rational in a complementary manner (Ornstein, 1972).

In conclusion, this chain of reasoning allows one to state that the teaching of elementary school mathematics through the indigenous games of Bhutanese children is an actualization of complementarity and an exemplification of ethnomathematics. Complementarity has been demonstrated through a pedagogical process that taps both hemispheres of the human brain. Complementarity has been demonstrated by integrating a child's world of play with a child's world of school. At a given moment in time, these worlds are mutually exclusive, but they are the worlds of the same unified child and since they are polar opposites, they do influence each other in a recursive and complementary manner (Sawada & Caley, 1986).

Propositional Theme III

Complementarity: Movement and Bhutanese Children

Development of the Working Hypothesis

It seems most fitting and opportune that this research was conducted during the 1987 year when the United Nations Children's Fund (UNICEF), the world organization for the well-being of children and the founding organization of TTC/DS, had as its calendar theme: "Learning to Grow." In the prologue of that calendar the following is stated:

> Children learn through their *senses and movement* [italics added]; each day is different and filled with new discoveries. Their first steps are as astounding as man's first steps on the moon. Their new experiences reawaken the child in the

> observing adult and recreate the sense of wonderment in learning and growing, for the world of children is an expanding spiral of consciousness of themselves, of each other, of adults, and of the natural environment around them. (UNICEF, 1987, p. i)

During the first five years of life, children learn predominantly through their senses and movement; thus, the kinesthetic sense, our sixth sense, plays a fundamental role in this learning and growing process (Balaskas, 1977; Blakeslee, 1980; Wittrock, 1977). Recall that kinesthesis refers to the sense of movement and position of the limbs that depend upon sensory receptors in joints, muscles and tendons (Talbot, 1977).

Furthermore, Steinhaus (1966) and Harris (1988) have claimed that man is "muscle-sense minded" because a larger part of the central nervous system is devoted to receiving and processing sensory input from the kinesthetic sense than is regulated to the eyes and ears combined. Ashlock and Humphrey (1976) assert that learning through movement has the added advantage of feedback. That is, a movement oriented learning medium can provide instantaneous knowledge of results because children can actually feel themselves jump, run, tag or be tagged. As a trainee at TTC/DS so aptly stated in reference to children learning through their bodies while in movement: "It is a teaching aid that children always have with them."

The mathematics educator Donald Albers (1981) has claimed that a child's body is the most powerful and richest source of mathematical knowledge that there ever was. He continued by asserting that their own body knowledge is a form of intuitive geometry and since they were born they have learned through their senses and movement that each day is different and filled with new discoveries.

The hemispheric brain research extends the importance of the complementary relationship between the two hemispheres by suggesting that the right hemisphere is

superior to the left in the kinesthetic mode (Carmon, 1970; Corkin, 1965; Fincher, 1984; Levin, 1973). It is also known that the left hemisphere is superior to the right in the verbal, linear, and sequential processing of information, and thus mathematical calculation (Blakeslee, 1980; Ornstein, 1972; Restak, 1984; Springer & Deutsch, 1981). As an educational implication of the split-brain research, Roger Sperry (1983) has stressed the seriousness of the situation in our elementary schools where such heavy emphasis is placed on communication and early training in reading, writing and arithmetic. He additionally asserted that in our school system the education of the right hemisphere is neglected at the expense of formal training for the left or major hemisphere. Therefore, what is required in the education of children is a holistic utilization of the above learning modalities, which will enhance children's understanding of reality through the complementary use of the two modes of knowing. Figuratively, speaking, we must heed the tacit message within Mulla Nasrudin's question: "Have you learned to swim?" (Shah, 1966).

In conclusion, the theoretical implications inferred in Chapters Two and Three, and the brief review outlined above have focused upon the complementary relationship between how a child learns prior to beginning school and how a child predominantly learns after entering school. In addition, the complementary relationship that exists between learning through the kinesthetic, holistic mode and acquiring knowledge through the verbal, analytic mode has been portrayed. Therefore, it is hypothesized that the teaching of elementary school mathematics through movement with Bhutanese children will be an actualization of complementarity.

The analysis proceeds by depicting descriptive accounts that demonstrate complementarity through a pedagogical practice that involves Bhutanese children learning mathematics through movement.

Demonstrative Accounts

Mr. U. T.'s Children, the Trainees, and the Concept of Matching. Mr. U. T. had recently indicated that he was focusing on the mathematical concept of matching; thus on Monday, 20 April when the researcher met with the trainees (XI batch) at 9 a.m., they discussed the mathematical concept of matching and how the trainees could possibly use their bodies in a mirroring fashion with Mr. U. T.'s children. Also, if the trainees wished they could use the song "I Can Count from 1 to 10", as the movement component of this song involves matching fingers. The trainees, then in partners, worked briefly on mirroring activities that involved matching body parts.

Following this they proceeded to the assembly ground to meet with Mr.U. T. and his children and discovered that ten children had been sent home because they were not in uniform. The resulting ratio of trainees to children was either 1:1 or 2:3. The entire group then moved onto the basketball and football (soccer) grounds where the actual procedural lesson took place.

Each group of trainees and children participated in physical activities that involved the children matching or mirroring the movement of a trainee. For example, one trainee had his child mirror the sequence of "Arm down, arm to the side, arm up" while two other trainees had children trying to superimpose their shadows on the shadows of the instructors. Another group of trainees, had their students doing jumping jacks, as well as jumping on one foot and then the other, while one student

teacher had his child walking behind him mirroring his walk and then a clapping sequence. As well, different groups taught the song "I Can Count from 1 to 10."

At the end of the 40 minute session all returned to their respective classrooms and during a discussion about the class, and as previously mentioned, one trainee stated the following in reference to children's bodies: "It is a teaching aid that children always have with them." During the lesson the children had expressed enthusiasm and joy, and later on that day Mr. U. T. remarked that many of the children continued the mirroring activity upon returning to their classroom.

Mr. T. N.'s Children, the Trainees, and the Concept of Measurement. On Wednesday, 20 May, in a mathematics methodology period, the trainees (XI batch) and the researcher discussed the concept of measurement and the best way to introduce linear measurement to Mr. T. N.'s children through the use of their bodies. The trainees suggested using traditional ways of measuring such as hand and arm spans, as well as strides, footsteps and finger walks.

The following four areas were utilized for instructional purposes: (a) Mr. T. N.'s classroom, (b) the library; (c) the veranda, and (d) the trainees' classroom. Children could be seen at each station using their hands, feet, and arms to measure distances; for example, in the trainees' classroom, one trainee had his student using hand spans to measure the height of a chair while another had his student measuring the length of the blackboard with his forearms. One student teacher's pupils measured the width of the trainees' classroom utilizing footsteps. Outside, on the walkway, a trainee's students were measuring the breadth of this area by the width of their hands. In the library a trainee had her student measuring the width of the library cabinets with arm spans.

In all four areas, and as the video-tape data revealed, the children made use of different body parts in the linear measurement of floors, walls, desks, chairs, windows, doors, blackboards, tables, books and each other's height. Again, the children showed a high participation activity ratio because of working in small groups, which were scattered throughout four instructional areas. Lastly, the children displayed an understanding of the concept of linear measurement by being able to measure and express distances in non-standard units.

Mr. T. N.'s Children and "Fire on the Mountain". On 16 June the researcher initially observed Mr. T. N. presenting a lecture focusing on how multiplication is fundamentally repeated addition. Mr. T. N. began by explaining the example, 2 x 6 = 6 + 6 = 12. He stated, "Six into two or two into six means two groups of six or six groups of two." He then wrote 2 + 2 + 2 + 2 + 2 + 2 = 12 on the blackboard and, for demonstration purposes, had twelve children come forward which were divided into six groups of two and then two groups of six.

"Look at the blackboard, sit down," exclaimed Mr. T. N. as he wrote 4 x 6. "Four into six, do you know the answer? Yes, you know, twenty-four. But what is the meaning of four into six? Four into six means?" The children stated, " Four groups of six or six groups of four. Mr. T. N. then wrote 4 x 6 = 6 + 6 + 6 + 6 = 24 on the blackboard and continued with a similar procedure in explaining how 8 x 3 = 24.

Next, Mr. T. N. asked the children if they would like to go outside to play a game and the children shouted, with smiling faces, "Yes, Sir, yes Sir!" After arriving at the northern tip of the football field the children were taught how to play the game "Fire on the Mountain." The children were told to form a circle and were instructed to run in an anti-clockwise direction while continuously shouting "Fire on the Mountain,

run, run, run!" When Mr. T. N. yelled a number, for example four, the children scurried to get into groups of four and then Mr. T. N. demonstrated through repeated addition that four multiplied by nine was equal to 36.

The video-tape data revealed that this movement activity lasted for over 40 minutes and that the children were constantly laughing, giggling, screaming, and hugging each other with joy, as they ran and then scampered about trying to find a group to join after a number had been called. In addition, through choral responses the children exhibited their understanding of these multiplication facts.

Mr. U. T.'s Children, the Trainees, and the Number Line. On 4 August Mr. U. T. took his children to the basketball ground. Working in pairs, the children were successful at constructing large number lines for the purpose of solving addition problems by jumping. For example, if a child had the problem 3 + 2 he or she initially stood on zero and then made three jumps, stopped and said plus two, and then made an additional two jumps. The child then would have landed on that point of the number line designated as five. This was significant, as the video-tape data revealed that during a previous lesson, on 29 July the children were unable to work independently because the lines that they had drawn were too short, and the numerals that they had constructed were too close together.

Again on 18 August the trainees (XII batch) worked with Mr. U. T.'s children utilizing the number line for teaching addition and subtraction of single digit numbers. For example, if the problem was 5 - 3 a child stood on zero, took five jumps forward, and then travelled three jumps backward. This sequence of jumping brought the child to that point on the number line designated as two.

The video-tape data disclosed that the children displayed a high level of time-on-task and a high activity ratio. Several trainees had the children create addition and subtraction problems for their classmates and got the children to record these questions on the ground. The children hopped on one foot, both feet, forward and backward while successfully solving addition and subtraction problems involving single digit numbers.

Mr. U. T.'s Class, the Trainees, and Measurement. On 21 October the researcher met with the trainees (XII batch) and they discussed the concept of weight as a subset of measurement. Further, the researcher asked the trainees what physical activities could be used to teach the concepts of "heavy, heavier" or "light, lighter" and the trainees suggested making use of stones. The trainees subsequently met with Mr. U. T.'s children on the assembly ground and were divided among the children at a ratio of 1:2 or 2:2. The children and the trainees dispersed and went to various locations on the assembly, volleyball, basketball and football grounds.

The video-tape data showed that the children were lifting, throwing, and carrying stones throughout the lesson and were successfully led by the trainees to verbally compare the stones with regard to weight. Some children could be seen throwing the stones in a "shot-put" fashion, which the Bhutanese refer to as "putting the stone", while other children threw the stone underhanded. Two trainees drew a circle from which their children "putted the stone" and emphasized the correct motor technique of propelling this object. Additionally, these trainees marked the landing spot so that their children could compare their stone throws. Lastly, two other trainees created a "seesaw" with wooden planks, lying nearby, and had their children compare their weight with that of a classmate.

In a later lesson on 6 November, Mr. U. T.'s children worked independently while focusing on the concept of "long, longer" through broad jumping. Also, the children reviewed the concept of heavy, heavier by lifting each other. The video-tape data revealed that the children worked autonomously and displayed a high level of time-on-task and again exhibited a high activity ratio because they worked in small groups which were dispersed throughout the basketball court. Lastly, the children were able to state which jump was longer and which child was heavier when making these comparisons.

Discussion

It has been stated that a child's body is the most powerful and richest source of mathematical knowledge that there ever was. D'Ambrosio (1981) has emphasized that the teacher's role must be one of helping a child to critically reflect upon his or her reality in order to discover how mathematics is inherent within a child's everyday life. Hence, it has been a goal of this chapter to portray how children can be given an opportunity to critically reflect on their perceived reality and discover how their bodies, and extensions of their bodies, can be a rich source of mathematical knowledge.

D'Ambrosio is a mathematics educator who is primarily concerned with mathematics education of children in the developing world. UNICEF is that branch of the United Nations which is primarily concerned with the well being of children in the developing world. However, UNICEF's (1987) statement that "Children learn through their senses and movement" (p. i) refers to all children of our planet. The significance of this point will be alluded to momentarily.

It can be concluded that Bhutanese children learning mathematics through movement is a complementary process because of the polar relationship that exists

between how children learn in the first five years of life and how they learn after entering school. Further, complementarity has been shown through the involvement of both hemispheres of the human brain by tapping the kinesthetic and verbal modes of knowing.

Children heaved the stone through the air and hence, stereognostically measured that object; then these same children learned to give that specific stone a verbal label of heavy or heavier. Thus we see a link between the kinesthetic and verbal mode and the right and left hemispheres. Further, since "putting the stone" is an indigenous activity it can be concluded that it can also be an ethnomathematical activity.

UNICEF's (1987) statement that children learn through their movement and senses, and the implication that this applies to all children of the world, allows one to infer, firstly, that a pedagogical process that is best for Bhutanese children may not be best for all children of the world. For example, this research suggests that Bhutanese children should learn mathematical skills through their songs because singing is an inherent part of their culture. Therefore, this pedagogical process is best for Bhutanese children, but may not be best for children from a country where the receiving and reproducing of sound is not such a dominant practice. Secondly, a pedagogical process that is best for children of the world may be best for Bhutanese children. These two conclusions are based on the fact that Bhutanese children are a subset of the World's children.

At this moment we reach the "turning point" (Capra, 1982), and that is a point in time when a realization occurs that the boundaries between countries and customs of cultures are man made. It has been said that the cultures of the East and West are in some sense polar opposites and thus complementary, but at the turning point the

uniqueness of one becomes the uniqueness of the other. At the turning point, movement transcends culture because children's movement is fundamental to the nature of all children of the human race.

As the dictionary definition of complementarity reveals, complementarity implies that something needs to be filled out, that something needs to be completed, and that something mutually supplies another's lack. Hence, Bohr's complementarity resolution that the nature of light is both particle-like and wave-like, hence, the need for science and religion, and hence, the need for the rational and the intuitive. However, in contrast to complementarity is "oneness", is "wholeness" in that if something is of oneness then there cannot be separate polar opposites. One cannot divide something which is inseparable, something which is perfect. The oneness of children is their fundamental nature and the evidence presented and this chain of reasoning leads one to conclude that the nature of children is that they are movement oriented. Children learn through their movement and senses.

However, and this argument is meant to be cyclical, the paradox is that children also need formal learning situations in order to *complement* learning through their movement and senses. At one moment in time, for example, prior to reaching school age, children learn predominantly through their movement and senses, and this medium is capable of educating the whole child. However, at a later stage in development, formal learning is also required for the holistic education of children. A child's world of schooling is complementary to a child's world of play.

In conclusion, Bhutanese children learning elementary school mathematics through movement is an actualization of complementarity, just as any child learning

elementary school mathematics through movement will be an actualization of complementarity.

Indicators of Student Achievement

Time-on-task

In an article entitled *What School Factors Raise Achievement in the Third World?* Fuller (1987) reports findings from more than 60 Third World investigations on what school characteristics do and do not appear to contribute to pupil achievement. These studies were categorized within five school factors, which were: (a) school expenditures, (b) specific material inputs, (c) teacher quality, (d) teaching practices and classroom organization, and (e) school management and structure (Fuller, 1987).

After reviewing 14 Third World studies which focused upon the school factor of "teaching practices and classroom organization", Fuller(1987) made the following conclusion: the duration of instruction was consistently related to improved student performance. That is, within these 14 studies the length of the instructional program, expressed as hours per day or days per week, was consistently related to higher student achievement. Fuller concludes by revealing that "the length of instruction was significantly related to achievement in 12 of 14 analyses" (p. 283).

The implication of this finding is that if students display a high level of "time-on-task" during their instructional sessions then achievement will be enhanced. This implication is based on the fact that educational researchers frequently utilize time-on-task as an indicator that learning is taking place (Borg and Gall, 1983). Thompson

(1988) concurs by stating: "Descriptive research has led to the importance of time-on-task as a process variable that relates to pupil learning" (p. 17).

For this research, the importance of this chain of reasoning lies with the qualitative analysis of the audio-visual and written documentation of time-on-task exhibited by Mr. U. T.'s PP A children and Mr. T. N.'s II B children during the instructional lessons. Fuller (1987) suggests that student time-on-task is an extremely important educational variable. He states:

> Classrooms vary enormously in the amount of time actually spent on instructional tasks rather than keeping order, checking each student's homework, or arranging lessons. And efficient use of classroom time is [also] related to pupil performance in industrialized nations. . . .Considerable progress on this potential of school efficiency could be made in the Third World--by sharpening classroom management and teaching skills within constrained levels of material inputs. (pp. 283-284)

Self-reports

Fuller (1987) continues by disclosing that pedagogical practices have received only minor attention from researchers working in the Third World. Out of the 60 studies reviewed, he reports only three studies that examined the effect of active learning through participation as compared to a chalk-and-talk pedagogical approach. One of these studies in rural Brazil discovered a consistent positive effect on pupil performance as a result of the number and variety of instructional activities reported by teachers. The teachers employed nine different activities, such as small work groups, dramatic reading, manual work, and storytelling. The results suggest that the variety and total number of activities helped to explain the high pupil achievement. Since this last study appears similar to this present investigation, more credibility can be given to the self-reports which follow.

Mr. T. N. In an article entitled *New Approach to Primary Education*, published within an educational document by the Department of Education, Bhutan (1988), Mr. T. N. made the following statement about the NAPE project and the children of this investigation:

> NAPE is the New Approach to Primary Education which deals with modern methods of teaching and learning in all subjects. . . .The NAPE program deals with relevant methodology and syllabus according to the situation of Bhutan. It emphasizes not only reading and writing but also other important roles in the development of children: physically, socially, emotionally, and intellectually. . . .The fruitful result of the NAPE program will not be seen in a year. When the children are brought up step by step, we can see the vast difference in learning. I see the example of my own children who are in their third year of a NAPE class. They have been in the NAPE program right from class one. After the third year of learning through NAPE, I can see lots of improvement in learning, understanding, reading and writing. I am proud to see their skills. When I was in standard V [class V], I didn't achieve the skills that they have now. I am sure that students of other NAPE schools who have been learning through the NAPE program for three years are more advanced and developed than other class III students of non-NAPE schools.

Further evidence in support of the NAPE project and this research is revealed by the fact that there has been a significant increase in attendance at NAPE schools, including the demonstration school of TTC/DS, not only by students (11%) but also by teachers (9%), since the implementation of the project in March of 1986 (Turner, 1988b). The reader may recall that one of the purposes of this research is to give support to the NAPE project. The former Director of Education stated at the first annual NAPE conference in August of 1986, that the challenge to the implementers and the teachers of this new pedagogical approach is to effectively integrate learning by rote with learning through active participation: a complementary task. Consequently, this research is in support of and an extension of the overall NAPE philosophy.

Mr. U. T. and his PP A Class. On 18 May 1987, Mr. U. T. was requested to interview separately each child of his class and pose the following questions: (1) Do you enjoy working with the trainees on Mondays? and (2) If yes, what do you like about working with the trainees? Mr. U. T. recorded on a checklist the children's responses and gave permission for this information to become part of the data for this research. Of the 34 children present, 28 (85.5%) said they liked working with the trainees while only 4 (12.5%) said they did not. Mr. U. T. stated that only eight students were able to verbalize why they liked the experience and of these eight, six students stated "songs" for their reason.

In a subsequent tape-recorded interview on 25 May 1987, Mr. U. T. and the researcher formally discussed the study thus far, and the results of the children's responses to the above two questions. Mr. U. T. was asked why he believed that the majority of his class enjoyed the lessons with the trainees. He stated that small groups, varied activities, going outside, and attention from the trainees were reasons for his children's positive attitude towards the classes.

In response to the question: What are your thoughts on learning mathematics through these activities? Mr. U. T. stated that after graduating from TTC/DS, he has been teaching PP for five years at the Demonstration School and has always made use of active learning. However, the variety and frequency of the activities this year had enabled his children to master being able to form their numerals and had solved a recurring problem involving the reversal of numerals such as three, six or nine.

A further indication of the overall achievement of Mr. U. T.'s children in the field of mathematics, was that, by the end of the year, they were able to progress to the class one mathematics syllabus and began subtraction of single digit numerals.

Mr. U. T. stated that this was the first time in his teaching career that almost all of his PP class had progressed to this level.

The Trainees. During Phase V: 10 August - 8 October 1987, the XI batch of trainees took part in their major eight week practice teaching assignment. These twenty-four trainees were designated to various primary schools in Bhutan and upon returning to TTC/DS after their practice teaching assignment, many trainees remarked how advanced Mr. T. N.'s class II were in comparison to other class IIs they had observed. However, it is important to note that all of the factors that Fuller (1987) delineates as being highly effective in boosting student achievement in Third World schools are present at TTC/DS and, more than likely, are not present at most other primary schools in Bhutan. These factors are: (a) text books and instructional materials, (b) years of teacher training, (c) school library activity, (d) length of instructional program, and (e) pupil feeding programs. This suggests that the pedagogical practice utilized in this research was probably a significant factor in contributing to the achievement of these pupils because of the instructional materials used as well as the high time-on-task exhibited by the students during their instructional program.

In the opinion of one trainee, Mr. T. N.'s children were progressing so well because of the use of small groups and because of the playway method which appeared to leave an imprint on the minds of these children.

Other Teachers. During Phase III: 3 June to 3 July 1987, the stone games of "Apeygodo" and "Boodeem" were introduced to Mr. U. T.'s PP A class for the purpose of teaching addition of single digit numerals. These stone games were observed by two other PP teachers and by the two class one teachers. Consequently,

the two PP teachers began to use these ethnomathematical games in the teaching of addition to their children. Further, the two class one teachers requested the researcher to conduct a one day workshop with their children utilizing these ethnomathematical games. This workshop was conducted on Saturday, 13 June 1987, and Apeygodo and Boodeem were subsequently used in the mathematics lessons of these classes for learning and practicing the fundamental operations of addition and subtraction.

The Researcher. In conclusion, Borg (1981) asserts that the significant advantage of direct observation is that it allows the researcher to collect direct data about human behavior that can be gathered only indirectly by such measurement techniques as a pen-and-paper test. For example, we can probably learn much more about children's attitudes toward a certain form of pedagogy by observing their interactions with one another while participating in the teaching medium, as compared to asking questions about the teaching strategy on a pen-and-paper test. Taking from Borg's ideas, and as aforementioned, the following questions would be well suited for study by direct observation: (a) What specific teaching strategies are most effective to teach basic number facts to Bhutanese children? and (b) How do Bhutanese children respond to a form of pedagogy that involves their songs, games, and movement.

Based upon direct observation, the chapters of this dissertation focusing on the "case record" and the "analysis and discussion" have reported that the children of this study were effectively taught elementary school mathematics through their games, songs and movement. Further, the above chapters as well as the audio-visual data disclosed that these children had a positive attitude towards this pedagogical process.

Summary

The concept of propositional theme has been used as the major vehicle for analyzing the case study data. In the context of this investigation, a propositional theme was a recurring behavioral pattern which denoted a fundamental truth that was shown through demonstration to be an actualization of complementarity.

Three such propositional themes were derived from the data: (a) Complementarity: The Voices of Bhutanese Children, (b) Complementarity: The Indigenous Games of Bhutanese Children, a .d (c) Complementarity: Movement and Bhutanese Children. For each propositional theme a corresponding working hypothesis was developed by focusing upon the implications of the theoretical research and the properties of the pedagogical activities that the children experienced. The three working hypotheses that correlate respectively with the above propositional themes may be stated as follows: (a) the teaching of elementary school mathematics through musical songs to Bhutanese children will be an actualization of complementarity, (b) the teaching of elementary school mathematics through indigenous games to Bhutanese children will be an actualization of complementarity, and (c) the teaching of elementary school mathematics to Bhutanese children through movement will be an actualization of complementarity.

Like the proof for a mathematical theorem, case study evidence was then presented in a demonstrative form in order to support each working hypothesis. The philosophical discussions that followed the first two propositional themes reflected how the singing, and the indigenous games of Bhutanese children were ethnomathematical activities that created a bridge, and thus a confluence between the cultural life of these

children and their world of school. The final discussion proposed that the fundamental nature of children, the "oneness" which all children share with each other, transcends their immediate culture. This fundamental nature of children was stated to be their natural drive to grow by learning through their movement and senses. The chapter concluded by focusing upon indicators of student achievement such as participant self-reports, that attested to the mathematical skills and knowledge gained by the children of this study.

CHAPTER SEVEN

SUMMARY, CONCLUSION, AND IMPLICATIONS

Summary

Bhutan, a tiny eastern Himalayan country, first opened its doors to the west a short three decades ago. Up until that time, Bhutan remained virtually unknown to the rest of the world. Hidden among the high Himalayan mountains, this small monarchy remained self sufficient with the exception of contact with India: its most influential neighbour.

The United Nations classifies Bhutan as one of the thirty-one least developed countries in the World having an estimated per capita income of U. S. $116.00 per year. Approximately 95% of the people are agrarian being mainly involved with subsistence farming and animal husbandry. Since the ratio of people to land is 25 per square kilometer, landlessness is not a problem and farmland is generally equally distributed.

In an effort to expand its economy from one solely based on agriculture and cattle rearing, Bhutan in 1961 initiated a series of five-year plans. The major goal of these plans has been to create a structural transformation in the socioeconomic system, and more concisely to change a barter system into a modern economy. Consequently, education has been designated by the Royal Government of Bhutan as a major focus for development (Strydonck, Pommaret-Imaeda & Imaeda, 1984). Schooling in Bhutan before the 1960s was mainly for a male population. Some boys would have had the

opportunity to attend a Buddhist monastery while a few children, whose parents could afford the expense, were sent to India for a formal education (Hasrat, 1980).

The total number of primary schools in Bhutan in 1987 was 149 and this was far from enough to house all of the school aged children. It is reported that only 25% of the primary aged population were enrolled in schools in 1987 and this reflects the low literacy rate of 23%. The literacy level and the number of children attending primary schools form the lowest levels in the south Asia region and are among the lowest in the world (Department of Education, Royal Government of Bhutan, 1988). It is important to note that Bhutan's primary education system is made up of one year of kindergarten followed by six years of formal schooling. However, this categorization was only implemented in March of 1987, as before that date children undertook two years of kindergarten before proceeding onward.

In order to combat its low literacy level and the small percentage of school aged children attending primary school, the Royal Government of Bhutan, as previously mentioned, initiated a series of five-year plans for the growth of the country and the fifth five-year plan (1981/82-1986/87) was aimed at creating a more solid educational foundation. More specifically, the fifth plan differed substantially from the previous plans in that rather than expanding educational infrastructure, it aimed at improving existing programs and facilities by: (a) enhancing the quality of education through curriculum reform, (b) upgrading teacher training programs, and (c) reorganizing technical education (United Nations Development Programme, 1985).

An example of this educational reform at the primary school level started in the spring of 1985 when the Department of Education began planning for the implementation of a different approach in the pedagogy of a new primary school

curriculum. At that time, and on behalf of the government of Bhutan, the Chief Inspector of Schools, requested a mathematics curriculum consultant through the World University Service of Canada (WUSC) and, thus, this investigator initially came to Bhutan for an eight week primary school curriculum development assignment and for the purpose of ascertaining the feasibility of conducting the present research.

Purpose

Pedagogy as an Actualization of Complementarity. Firstly, what is of such extreme importance in the development of education within Bhutan is the method by which elementary school mathematics is taught. Barcellos (1981) has asserted that primary school curriculum throughout the world is basically the same but the needs of children in the Third World are distinctly different from those of children from industrialized countries. This international mathematics educator also stresses the vital significance of how mathematics is taught to children in developing nations. He infers that children in the developing world find it difficult to apply the mathematics that they have learned because they have learned it from outside of their own culture. Consequently, Barcellos affirms that these children cannot see how the mathematics that they have acquired in school relates to the world in which they live.

This research described and examined a medium of instruction for elementary school mathematics which had a meaningful relationship to the cultural world in which Bhutanese children live; that is, the world of their games, songs and movement activities. In addition, it was a purpose of this investigation to defend that this pedagogical approach was an actualization of the principle of complementarity.

It was in the Italian city of Como, during the 1927 International Congress of Physics that Niels Bohr initially introduced his formulation of the principle of

complementarity (Holton, 1973). Bohr's proposal was that we must accept the inescapable dichotomy that the nature of light is both wave-like and particle-like depending upon how it is observed. He stated that these two descriptions of this phenomenon are complementary; that is, each perspective is required to give a complete description of atomic reality.

The Nobel Laureate, Niels Bohr firmly believed that the principle of complementarity had wide application outside the realm of physics and stated that one day complementarity would be taught in schools and become part of public education (Holton, 1973). Further, Niels Bohr's deep commitment to the principle of complementarity, and to the antiquity of its roots, is revealed by the fact that he chose the Buddhist t'ai chi symbol for his coat-of-arms when he was knighted by the Government of Denmark. The physicist, Fritjof Capra (1983) reveals the powerful significance of this decision to be Niels Bohr's acknowledgement of the profound harmony and complementary relationship between modern Western science and ancient Eastern wisdom. Consequently, Bhutan, the only country in the World where Mahayana Buddhism is the state religion, was an ideal setting for an investigation focusing upon the furthering of complementarity as a new espistemology.

In addition, this research intended to extend the principle of complementarity through the results of the most recent research on hemispheric specialization of the human brain. The Nobel Laureate, Roger Sperry and his colleagues proved that the corpus callosum united the special talents of both hemispheres. Their ingenious tests demonstrated that humans are undoubtedly of two minds, one specializing in analytical and verbal skills, the other adept in space and pattern perception. The left hemisphere deals with the abstract symbols of language and numbers. It is logical, linear, and

sequential in processing information. The left hemisphere sorts out parts. In contrast, the right hemisphere was found to grasp things as a whole. It generates mental images of the senses and movement. It is holistic and simultaneous in its processing of information (Fincher, 1984; Restak, 1984; Springer & Deutsch, 1981).

Most recently, what has emerged from the of hemispheric specialization research is the realization that the cerebral hemispheres function in a complementary manner (Capra, 1983; Levine, 1984; Ornstein, Thompson & Macaulay, 1984; Silverstein & Silverstein, 1986). Rather than viewing one hemisphere as being major or minor as in the theory of cerebral dominance, scholars are proposing that the intuitive, holistic thinking right hemisphere complements the analytical, linear processing left hemisphere.

It has been shown that there are two complementary modes of knowing which have been most strongly revealed through the study of science and religion. Recently, these two complementary modes of knowing have been given further support by contemporary research on hemispheric specialization of the human brain. Paradoxically, our brain is structured and functions in a complementary manner: our brain is structured and functions as a whole.

Complementarity as a Theoretical Structure for Ethnomathematics. The second purpose of this investigation centered upon how complementarity could be considered as a theoretical structure for the concept of ethnomathematics.

The Brazilian mathematics educator Ubiratan D'Ambrosio (1981) is credited with coining the term ethnomathematics. He created this concept in the context of developing countries who are striving for a more meaningful way to instruct their children in the field of mathematics.

Scott (1985) indicates that ethnomathematics lies at the meeting place of cultural anthropology and mathematics. He states that it has been referred to as math in the environment or community, and focuses upon how specific cultural groups go about the tasks of counting, ordering, sorting, measuring, and weighing in their daily lives. Therefore, the Himalayan Kingdom of Bhutan, being classified by the United Nations as one of the thirty-one least developed countries of the World, was an appropriate setting to investigate how complementarity could be considered as a theoretical framework for the concept of ethnomathematics.

To reiterate, the two research questions that were examined by this investigation were: firstly, how pedagogy, which involved teaching elementary school mathematics through the songs, games, and movement of Bhutanese children, could be an actualization of complementarity; and secondly, how complementarity could be a theoretical structure for ethnomathematics.

The Value of this Research for Bhutan

The two primary teacher training institutions in Bhutan, namely, the National Institute of Education (NIE), Samchi and the Teachers' Training Centre and Demonstration School (TTC/DS), Paro, jointly planned and implemented the same primary teacher education curriculum in July of 1986. This curriculum recommended teaching primary school mathematics through such physical activities as: sandplay, mudplay, stoneplay, rhythm and movement, circle games, running games, marble games as well as archery, khuru, and dego. Thus, a value of this research was the documentation of data which examined and supported this pedagogical recommendation.

Further, a new primary school curriculum and pedagogical approach was implemented by the Department of Education in 12 pilot schools along with the Demonstration School of TTC/DS in March of 1986. This curriculum development project, entitled the New Approach to Primary Education (NAPE), stresses the active involvement of children in the learning process and the children's immediate environment becomes the focus and stimulus for subject matter studied. At the first NAPE conference in August of 1986, the former Director of Education of Bhutan asserted that the challenge for teachers within the NAPE program was to effectively integrate learning by memorization with acquiring knowledge through active participation. Therefore, research was needed to depict and examine this process in order to assist with nation wide implementation of the NAPE project in the early 1990s.

Lastly, in Bhutan 1:4 of school aged children attend primary schools and of this 1:4, only 1:4 will complete class six (Beyon & De Spiegeleer, 1985; Department of Education, Royal Government of Bhutan, 1988). The government of Bhutan, with this knowledge, believes that the NAPE project has the potential to help children acquire necessary life sustaining mathematical and language literacy skills prior to returning to their village farm. More specifically, these skills will enable children to increase their knowledge in the areas of hygiene, sanitation, and nutrition before returning to their homes. The government of Bhutan then believes that these children can help to prevent the greatest killer of children in Bhutan, that being dehydration due to malnutrition and diarrhea. Therefore, by assisting children to gain mathematical literacy through an integrated pedagogical approach utilizing activities personally meaningful to Bhutanese children, Bhutan's educators believe that schooling will be more life enhancing. It was the intention of this research to support such a belief.

The Rationale for and Procedures of the Methodology

The Case Study. Within a naturalistic paradigm, a case study, with the researcher as a participant observer, was chosen as the means by which to investigate how pedagogy could be an actualization of complementarity, and how complementarity could become a theoretical structure for ethnomathematics.

Guba (1981) and Guba and Lincoln (1982) indicate that educational research during the past decade has increasingly made use of the naturalistic paradigm. They additionally reveal that the distinguishing features of this paradigm are that it is carried out in a natural setting which utilizes the case study format, and that it relies strongly on qualitative research methods.

The case study method is a form of descriptive research which involves intensive investigation of one social unit. Its objective is to comprehend the life cycle or a significant part of the life cycle of the unit under study. Borg (1981) states that direct observation is an essential and major technique for gathering data within a case study and asserts that it allows the researcher to collect direct data about human behavior that can be gathered only indirectly by such assessment techniques as a pen-and-paper test. Borg further states that the following questions are well suited for study by direct observation: "What specific teaching strategies are most effective to teach basic number facts to children? How do preschool children respond to a television program that contains a high number of violent acts?"(p. 132). For the purpose of this investigation, Borg's questions have been rephrased to read: What specific teaching strategies are most effective to teach basic number facts to Bhutanese children? How do Bhutanese children respond to a form of pedagogy that involves their songs, games, and movement activities? Lastly, another important reason why the

case study was an appropriate medium for investigating the research questions, was that the case study has been acclaimed to be a form of methodology that can contribute significantly to the development of theory (Stake, 1978).

The Research Setting. Approval was granted to the investigator by the Department of Education, Royal Government of Bhutan to conduct this research during the 1987 school year. The Teachers' Training Centre and Demonstration School (TTC/DS) was an ideal setting for this investigation based upon the criteria delineated by Spradley (1980), which are: (a) simplicity, (b) accessibility, (c) unobtrusiveness, (d) permissibleness, and (e) frequently recurring activities. Further, TTC/DS was an appropriate setting in that it has historically been regarded as an experimental and exemplary institution, and this research marks the first scholarly form of investigation that has been conducted at TTC/DS since its inception in 1974.

The Subjects. The New Approach to Primary Education (NAPE) and its curriculum were implemented at the Demonstration School of TTC/DS in March of 1986. Since this new pedagogy and curriculum only went up to class three, two teachers from pre-primary to class three, who had expressed a keen interest in the study, were chosen along with their classes (PP A and II B) to participate in the investigation. In addition, the twenty-four second year and twenty-nine first year primary teacher trainees, referred to respectively as "Batches XI and XII," acted as facilitators in the teaching of elementary school mathematics through the songs, games, and movement activities of Bhutanese children.

Collection of Data. The primary research instrument in a case study is the researcher as the participant observer (Eisner, 1981; Herriott & Firestone, 1983; Merriam, 1988; Wilson, 1977). The credibility and trustworthiness of this research

was enhanced by the fact that the researcher received guidance and consultation in the collection and interpretation of the data from an anthropologist who had conducted her dissertation research in Bhutan, and was working as a history consultant for the Department of Education during the period of this investigation. Further, the internal trustworthiness of this study was achieved through daily discussions with Mr. T. N. and Mr. U. T. concerning the researcher's interpretation of the data. The video-tape films also acted as a triangular verification of the investigator's interpretation of the data collected.

The data collected was primarily in the form of field notes. These field notes were complemented and supplemented by audio-visual data that was collected by means of a tape-recorder, a slide film camera, and a video camera.

During a typical week of data collection four lessons were observed. Two lessons involved the trainees assisting Mr. U. T.'s or Mr. T. N.'s children to more fully understand a mathematical concept or problem by using a medium that involved games, songs or movement activities. The second lesson that each group of children experienced was intended to be a follow-up to the initial lesson and was intended to enable the children to repeat, practice, and apply what they had learned. The classroom teacher was the primary facilitator in the follow-up lesson.

Analysis of Data. As recommended by Merriam (1988) the analysis of data had three hierarchical levels, they being: (a) the descriptive account, (b) the creation of themes, and (c) the development of theory. The descriptive chapter focused upon a rich, thick and imagery filled account of the data, and had as its major objective the transporting of the reader to the research setting.

Next, the analysis focused upon the creation of themes and the development of theory from the data. A theme was a behavioral pattern that frequently recurred in the case study so as to characterize it. This research presented the analytical concept of "propositional theme" and utilized it in the examination of the data. The word propositional was used in its mathematical sense and denoted a formal statement of truth to be demonstrated. In the context of this investigation, a propositional theme was a recurring behavioral pattern, which denoted a fundamental truth that was shown through demonstration to be an actualization of complementarity. Three such propositional themes were derived from the data, they were: (a) Complementarity: The Voices of Bhutanese Children, (b) Complementarity: The Indigenous Games of Bhutanese Children, and (c) Complementarity: Movement and Bhutanese Children. This led to the third level of analysis, which was the development of complementarity as a theory for and rationale of a pedagogical process, as well as the principle of complementarity becoming the theoretical structure for the concept of ethnomathematics.

Conclusion

This section of Chapter Seven will be divided into two parts. The initial segment of the conclusion will deal with a formal logical scheme that focuses upon the two research questions of the investigation. The second segment will address the question as to how this research has made an original contribution to knowledge and to the development of education in Bhutan.

Formal Logical Scheme

In order to state the final inferences of this research it is necessary to reiterate the research questions. In summary, two research questions were examined in this investigation, they were: (a) how pedagogy, which involved the teaching of elementary school mathematics through the songs, games, and movement of Bhutanese children, could be an actualization of complementarity; and (b) how ethnomathematics could be given a theoretical structure by the principle of complementarity.

Through the use of formal logic, the relationship between and among the above three concepts will be demonstrated and the necessary conclusions will be established. The first research question, "pedagogy as an actualization of complementarity," will function as the major premise in this formal argument. The realization that ethnomathematics can be exemplified by pedagogy functions as the minor premise, in this chain of reasoning.

This logical scheme will demonstrate the connections between and among the major and minor premises and the conclusion. This formal argument will be divided into two levels. Level I: Relationship attempts to show that a logical relationship does exist between and among the three concepts of the research questions, and Level II: Establishment attempts to illustrate this relationship.

Once again the three concepts may be stated as: (a) the pedagogy of elementary school mathematics through the songs, games, and movement of Bhutanese children. (b) the principle of complementarity; and (c) the concept of ethnomathematics. Respectfully, the following three terms will be used in the premises of the formal argument: (a) pedagogy, (b) complementarity, and (c) ethnomathematics. The formal logical scheme follows.

Level I: Relationship

Major Premise: Pedagogy is related to Complementarity.

Minor Premise: Ethnomathematics is related to Pedagogy.

Conclusion: Ethnomathematics is related to Complementarity.

At this relational level a connection has been drawn from the analysis of the data, which demonstrates an interrelationship between and among pedagogy, complementarity, and ethnomathematics.

Progressing to the establishment stage, the relationship between these three concepts will now be illustrated.

Level II: Establishment

Major Premise: Pedagogy is an actualization of Complementarity.

Minor Premise: Ethnomathematics is actualized by Pedagogy.

Conclusion: Ethnomathematics is an actualization of Complementarity.

Consequently, this research concludes that the examination of the evidence in light of the theoretical orientation allows one to infer that: ethnomathematics can be given a theoretical structure and, thus, can be explained by the principle of complementarity *when* ethnomathematics is actualized by pedagogy.

Contributions of this Research

To Scholarly Knowledge. The physicists, Niels Bohr (1958a), J. Robert Oppenheimer (1954), and Merle Tuve (1967) all believed and asserted that the principle of complementarity had wide application outside the realm of physics. This research has demonstrated that the principle of complementarity can function as a theoretical structure for a form of pedagogy that unites a child's world of play with a child's world of school. Further, this form of pedagogy has been shown to be an example of

ethnomathematics; hence, the principle of complementarity has been used as an explanation and theoretical structure for ethnomathematics. Lastly, the principle of complementarity has been extended by the most recent research on hemispheric differences within the human brain. It has been this extension of the theoretical validity of complementarity and the use of complementarity in the explanation of human behavior, that allows one to state that this investigation has made an original contribution to knowledge and a further expansion of complementarity as a new epistemology. In short, this research has been a realization of Niels Bohr's belief that complementarity could one day become part of public education.

To Bhutan. Firstly, research support has been systematically documented for the pedagogical recommendation within the new curriculum of the two teacher training institutions of Bhutan, that children can successfully be taught mathematics through such activities as sandplay, mudplay, stoneplay, circle games, throw and target games as well as other traditional games. It should be noted that in December of 1987 and April of 1988 teacher education curriculum revision meetings were respectively held at NIE and TTC/DS. This research was used to support the above pedagogical recommendation which, thus, remained within the mathematics methodology section of the revised primary teacher education curriculum. This revised curriculum was implemented at NIE and TTC/DS in July of 1988 (Turner, 1988a, 1988b). In a statement by Thornley (1985), contained within the Canadian Development Agency (CIDA) publication of *Development (Education)*, he concurred with the international contribution of research such as this by affirming that:

> Platoons of classroom teachers have given way (a sign of progress) to smaller numbers of specialists responding to precise requests for help in crucial areas, such as curriculum development or teacher training. (p. 1)

Secondly, in December of 1988 the researcher received correspondence from the Chief Inspector of Schools, Department of Education, Bhutan outlining three alternatives for the future of the New Approach to Primary Education (NAPE) project. They were: (a) introduce the new system "as is" in all schools, (b) introduce a revised NAPE approach in all schools, or (c) reintroduce the old system that was present prior to the implementation of the NAPE project in March of 1986. Consequently, the results of this investigation should assist Bhutanese education policy decision makers as to the future of the NAPE project in the early 1990s.

Implications

For the Education of the Whole Child

Hemispheric brain research suggests, as does the t'ai chi symbol of yin and yang, that there are two ways of knowing. One is rational, analytic, the other intuitive, synthetic. The scientist is known for rigorous logic, the artist for spontaneous intuition.

This research suggests that children can learn mathematical literacy and problem solving skills through a pedagogical approach that taps both hemispheres of the human brain, that taps the two major ways of knowing, thinking, and responding. The functions of each hemisphere are complementary and, thus, create a singular, whole personality and intellect. We, as educators, must heed the words of Roger Sperry (1983) and Joseph Bogen (1975) and educate the total brain or we are sure to produce imbalanced people. Therefore, an education, which includes dance, drama, music, and

art as well as physical education must be given equal status to that of the "3Rs" in curriculums throughout the world, if development of the whole child is to be realized.

A further significance of this pedagogical approach can be noted by teachers who have observed that some children in problem solving situations use verbal symbols more proficiently than visual ones, and other children do better at solving the same problem using visual-spatial relations. Therefore, children should be given the opportunity to solve problems in a visual and spatial manner in contrast to only working in a highly verbal mode. This research has offered a method of instruction that draws upon the complementary functioning of the human brain and, thus, has the potential to educate the whole child in a holistic manner.

For Future Research

Within the article entitled, *Third World School Quality: Current Collapse, Future Potential,* Fuller and Heyneman (1989) state that:

> Research in developing countries should however, provide more textured portraits of life in classrooms. . . . Anecdotes abound regarding the chalk-and-talk pedagogical method employed by many Third World teachers. But we have few concrete descriptions of how teachers interact with pupils, how student exercises are structured and evaluated, and what forms of knowledge are communicated. . . .In short, we know very little about how teachers try to motivate children, or whether they attempt simply to maintain order when confronted by 50 or 60 young faces. (p. 17)

Thus, the value of this research is extended by having provided the first comprehensive, textured, and longitudinal description of the "lived experience" of two Bhutanese primary classrooms at TTC/DS. Moreover, longitudinal studies of this nature are needed in other primary schools of Bhutan as well as other primary schools throughout the Third World. Fuller (1987) supports the value of longitudinal studies at this time in Third World educational research by stating:

> In general, we are making judgements based only on cross-sectional evidence. Longitudinal work would strengthen causal inferences and bolster the quality of advice given to local educators and policy-makers. (p. 287)

Also, and as previously stated, Fuller (1987) reports findings from 60 Third World investigations on what school factors do and do not appear to contribute to pupil achievement. One of the school factors earmarked was "teaching practices and classroom organization" and within this category only three studies examined the extent to which active learning through participation influenced student achievement. Two of these studies simply introduced class discussion as the form of active learning. Therefore, future research is required to assess the impact of active learning, as put forth in this study, on student achievement.

In addition, supplementary research is required concerning the complementary relationship between active learning and learning by rote in elementary school mathematics as well as other subject areas. Research of this nature could further investigate the principle of complementarity as a basis for epistemology. Lastly, research focusing upon the complementary relationship between math in the environment and math in the classroom could strengthen the concept of ethnomathematics and further extend the principle of complementarity as a theoretical structure for ethnomathematics.

For the NAPE Project

The international educationalists, Fuller and Heyneman (1989) also report a study conducted in Nigeria and Thailand in 1987 where it was found that teachers spent 66% of their time lecturing to children, and when they did ask questions, a choral, factual response was expected. In contrast, the concrete descriptions of this research between teacher and student, as well as student-teacher and student, suggest that

children have a positive attitude towards participation in instructional activities, that involve their play, songs, and movement and that produce a high level of time-on-task and a high activity ratio. An important educational implication for Bhutan is that this pedagogical approach can be effective in creating a positive learning environment by synthesizing learning by rote with learning by activity. Therefore, this research intimates that the NAPE approach can be effective in the primary schools of Bhutan.

For the Survival of Children

Most importantly, the educational implication of this research for Bhutanese children is that they can learn fundamental mathematical skills through an ethnomathematical medium that involves the study of their play, songs, and movement. Consequently, it is possible for the three in four children that begin primary school in Bhutan, and subsequently return to their farming village before completing class six, to see how the mathematics that they have learned in school is a part of and relates to their culture.

The vital significance of this final implication for Bhutan may be seen by focusing upon UNICEF's "GOBI" project. The acronym GOBI represents the growth monitoring, oral rehydration, breastfeeding, and immunization of children in the Third World. The ultimate objective of the GOBI project is to allow citizens of the Third World to acquire "Health."

> Health, for a citizen of the Third World means the right to see your children survive to become adults; to lead a better life without being disabled by blindness, paralysis, or chronic fever--and, in the poorest countries, to have some hope of living beyond age 45. These are basic rights that should be denied to no-one. (Thornley, 1988-89, p. 1)

However, in order for a person of the developing world to effectively benefit from the GOBI project he or she must have basic numeracy and literacy skills. For example,

growth monitoring can detect invisible malnutrition by weighing children every month and then recording this statistic on growth charts. Consequently, a parent must understand how to measure, how to interpret the measurement, and be able to perform addition and subtraction skills in order to discover whether her child is gaining or losing weight. In some parts of the Third World parents can take their children to health clinics, but this is not always the case in the remote areas of the high Himalayas in Bhutan.

ORT, or oral rehydration therapy, now saves about 500,000 lives each year in the Third World (Meehan, 1988-89). The ORT mixture is a solution of salt and sugar which is prepared in a specific proportion with water and administered to a child suffering from dehydration due to diarrhea: the killer of five million children in the developing world in 1987 (Meehan, 1988-89). But again, a parent, usually a mother, the primary health giver, must have basic numeracy and literacy skills to be able to prepare the solution and administer it to her child properly.

Breastfeeding and immunization complete the GOBI acronym, but once more immunization involves being able to comprehend a health record card and to realize the next time that a specific vaccination is required. Thus, parents must learn how to count, order, sort, measure, and weigh, in addition to acquiring basic literacy skills. UNICEF estimates that seven million lives each year could be saved if the GOBI techniques were effectively applied on a world wide scale (Meehan, 1988-89).

The educational implication of this research is that children can learn through their play the basic numeracy skills necessary to efficiently and independently administer the GOBI techniques. Recall that only 1:4 children who begin primary school in Bhutan will complete class six. This level represents one of the lowest in the

world and portrays the vital significance of children learning basic mathematical skills through a medium which is part of their environment. As D'Ambrosio (1985) has stated, if teachers can guide children to critically reflect upon their perceived reality, then these children can see how the mathematics that they study in school relates to the world in which they live. For the children of the Third World this can be the difference between life and death.

It seems fitting to conclude this dissertation with a paradoxical and, yes, complementary message from UNICEF's 1987 calendar: *Learning to Grow.*

> The colour photographs selected for this edition represent many of the ways by which children learn--through everyday activities, imitation, practice and instruction. *They are shown both in spontaneous activities which largely determine how they acquire knowledge, as well as in more formal learning situations* [italics added]. (p. i)

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